TECHNICAL REPORT A-88-9



US Army Corps
of Engineers
Waterways Experiment
Station



# AQUATIC PLANT IDENTIFICATION AND HERBICIDE USE GUIDE

## VOLUME II: AQUATIC PLANTS AND SUSCEPTIBILITY TO HERBICIDES

Howard E. Westerdahl and Kurt D. Getsinger
Editors



AQUATIC PLANT CONTROL
RESEARCH PROGRAM
November 1988

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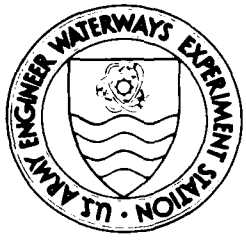


**AQUATIC PLANT CONTROL RESEARCH PROGRAM**

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# AQUATIC PLANT IDENTIFICATION AND HERBICIDE USE GUIDE

## VOLUME II: AQUATIC PLANTS AND SUSCEPTIBILITY TO HERBICIDES

by

Howard E. Westerdahl, Kurt D. Getsinger, Editors

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

November 1988
Final Report



Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

# PREFACE

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP) (Appropriation No. 96X3122, Construction General). The APCRP is sponsored by the US Army Corps of Engineers (USACE) and is assigned to the US Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). The USACE Technical Monitor for APCRP is Mr. E. Carl Brown.

The purpose of this document (presented in two volumes) is to provide guidance to Corps District and Project personnel on aquatic plant identification, herbicide susceptibility of selected aquatic plants, registered herbicide selection, herbicide use, and pertinent environmental considerations in the use of herbicides.

Volume I of the guide discusses site factors that affect herbicide selection, fate processes of herbicides in aquatic environments, and adjuvant selection, including application equipment and calibration procedures.

Volume II emphasizes priority nuisance aquatic plants, on a nationwide basis, and lists all of the registered herbicides for reservoirs and riverine environments. A short synopsis of each registered herbicide's label and toxicity to nontarget organisms is provided to assist in the selection process.

Dr. John Rodgers, Institute of Applied Science, North Texas State University, Denton, TX, prepared the sections on site factors affecting herbicide selection and fate in aquatic environments. Mr. Ron Hoeppel (formerly of WES, now with Naval Facilities Engineering Command in Point Hueneme, CA) provided assistance to Dr. Howard E. Westerdahl, WES, in compiling the summary label information on each herbicide and the reference materials listed in the appendixes. Dr. Kurt Getsinger, WES, prepared the adjuvant section. Mr. Richard Cromwell, University of Florida, Gainesville, FL, compiled the section on equipment selection and calibration. Appreciation is expressed for the assistance of the US Environmental Protection Agency's Registration Division in providing copies of Section 18 and 24c permits (Appendix D, Volume I), and the US Army Engineer District, Jacksonville, for information given in Appendixes E, F, and G (Volume I).

The aquatic plant identification section was partially completed by Dr. Robert Mohlenbrock of Biotic Consultants, Inc. Supplemental photographs and amended plant descriptions were provided by Dr. Getsinger and Mr. W. Reed Green, WES; Dr. William Haller, University of Florida; and the State of Florida Department of Natural Resources, Tallahassee, FL. The herbicide susceptibility section was prepared by Dr. Westerdahl, WES.

The Principal Investigator for this study was Dr. Westerdahl, Aquatic Processes and Effects Group (APEG), Ecosystem Research and Simulation Division (ERSD), EL, under the direct supervision of Dr. Thomas L. Hart, Chief, APEG, and under the general supervision of Mr. Donald L. Robey, Chief, ERSD, and Dr. John Harrison, Chief, EL. Mr. Lewis Decell was Program Manager of APCRP. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory (ITL). Design and copy layout were

accomplished by Ms. Betty Watson, ITL; typesetting of the text was performed by Ms. Annie Mae Kelly, ITL.

This document was reviewed for technical accuracy by the parent chemical companies of the aquatic herbicides discussed herein. Appreciation is also expressed to the many experts in aquatic plant management operations and research who reviewed and provided comments on improving this guide.

COL Dwayne G. Lee, CE, was the Commander and Director of WES. Technical Director was Dr. Robert W. Whalin.

This report should be cited as follows:

Westerdahl, Howard E., and Getsinger, Kurt D., eds. 1988. "Aquatic Plant Identification and Herbicide Use Guide; Vol II: Aquatic Plants and Susceptibility to Herbicides," Technical Report A-88-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

## CONTENTS

# INTRODUCTION

This volume was prepared to assist Corps of Engineers personnel in the identification of the nuisance aquatic plants typically found in Corps reservoirs and navigable streams. The list includes aquatic grasses, emergent plants, floating plants, and submersed plants. The user of this guide may encounter plants in the field that are not addressed herein, especially if the plants are a localized problem species. This field guide is a companion to Volume I, a desk reference entitled "Aquatic Herbicides and Application Equipment."

Several other guides for plant identification and herbicide use are available which may supplement information found in this guide:

- "A Guide and Key to the Aquatic Plants of the Southeastern United States," by Don E. Eyles and J. Lynne Robertson, Public Health Bulletin No. 286, 1944 (available from: US Public Health Service, Washington, DC 20314).
- "Common Marsh, Underwater & Floating-leaved Plants of The United States and Canada," by Neil Hotchkiss, 1972 (1st ed.) (available from: Dover Publications, 180 Varick Street, New York, NY 10014).
- "Aquatic and Wetland Plants of Southwestern United States," by D. S. Correll and H. B. Correll, 1975 (Vol I & II) (available from: Stanford University Press, Stanford, CA 94305).
- "Aquatic and Wetland Plants of Florida," by David P. Tarver, John A. Rodgers, Michael J. Mahler, and Robert L. Lazor, 1980 (available from: Florida Department of Natural Resources, Tallahassee, FL 32301).
- *A Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland*, by J. T. Kartesz and R. Kartesz, 1980 (available from: University of North Carolina Press, Chapel Hill, NC 27514).
- "A Guide to Pacific Wetland Plants," by L. Stemmermann, 1981 (available from: US Army Engineer District, Honolulu, Fort Shafter,HI 96858-5440).
- "National List of Scientific Plant Names," SCS Publication TP-159, 1982 (available from: Soil Conservation Service, US Department of Agriculture, Washington, DC 20013).
- *Herbicide Manual*, by Gary W. Hansen, Floyd E. Oliver, and N. E. Otto, 1983 (1st ed.) (available from: US Department of the Interior Bureau of Reclamation, Denver, CO 80202).
- *Herbicide Handbook*, 1983 (5th ed.) (available from: Weed Science Society of America, 309 West Clark Street, Champaign, IL 61820).
- *Weed Control Manual*, published annually (available from: Ag Consultants, Inc., 37841 Euclid Avenue, Willoughby, OH 44094).

## HOW TO USE THIS AQUATIC PLANT IDENTIFICATION GUIDE

Following this explanatory note are the names, descriptions, illustrations, and photographs of the aquatic species of plants covered in this guide. A narrative glossary and an illustrated glossary precede the descriptions and illustrations.

For each species there are two names at the top of the page that give the major classification categories (see PLANT DESCRIPTION FORMAT that follows). The first name is ferns, monocotyledons, or dicotyledons, indicating the major group to which the plant belongs. Ferns are those plants that reproduce by structures known as spores; ferns do not produce flowers. Monocotyledons are flowering plants that contain only one seed leaf, or cotyledon. They usually have parallel venation in their leaves and have flower parts usually in multiples of three. Members of the grass family are examples of monocots. Dicotyledons are flowering plants that contain two seed leaves. They usually have netted venation in their leaves and have flower parts in multiples of fours or fives. After the designation of fern, monocotyledon, or dicotyledon, the scientific name of the family is indicated. A family is a group of similar plants all sharing a set of common characteristics.

The scientific name of the plant appears next. It consists of two Latin names. The first is called the genus name. This is followed by the species name. After these two Latin names is one or more abbreviations that stand for the name (or names) of the botanist(s) who first gave the plant its correct name. These abbreviated names are referred to as the authority. If a different scientific name has been in common use for a plant, that name appears on the next line following the abbreviation "Syn.," which stands for synonym. The scientific names used are those recognized by Kartesz and Kartesz (1980). The common names that are indicated are those in general use in North America.

A description of each plant is given next. This description covers the important features used in identification.

Following the description is a habitat code, modified from that used by Stemmermann (1981). These codes, with a brief explanation, are:

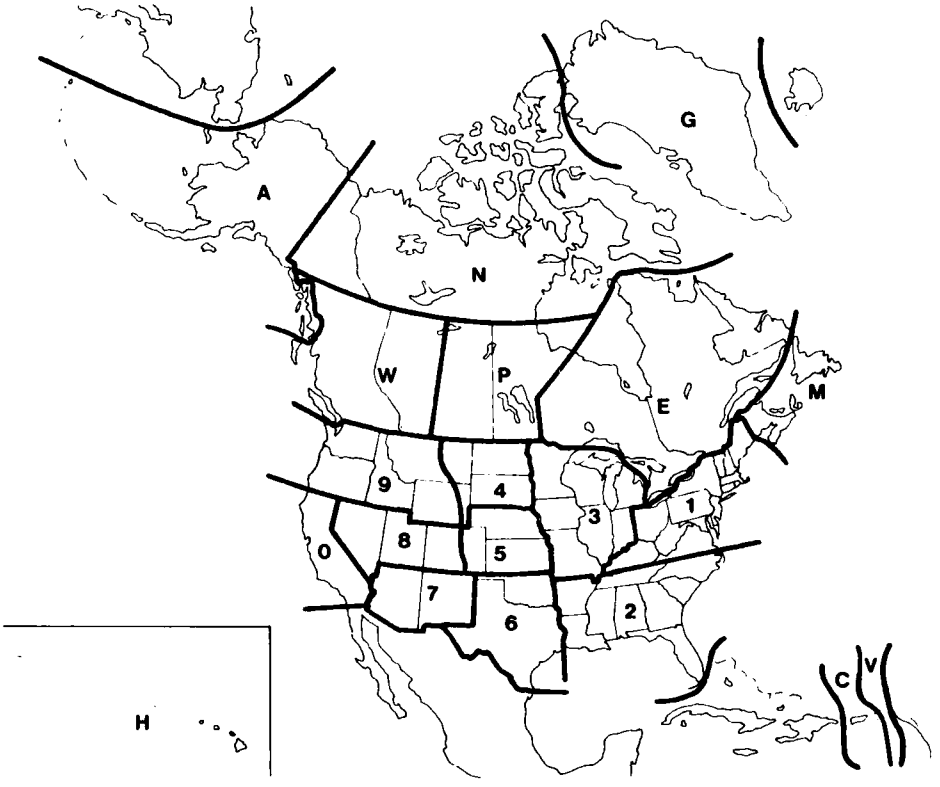
- **FA** - Freshwater Aquatic. This is a habitat permanently flooded by freshwater. The plants that live in this habitat may be submersed, partially submersed, emersed, or floating.
- **FM** - Freshwater Marsh. This habitat is dominated by herbaceous plants that are emersed species. Grasses, sedges, and rushes are the most common herbaceous components of the freshwater marsh.
- **FS** - Freshwater Swamp. This habitat consists of those areas where the soil is more or less permanently saturated.
- **SA** - Saltwater Aquatic. This is a habitat permanently flooded by saltwater. The plants in this habitat are mostly submersed and often form extensive beds.

**F** - Facultative Wetland Plant. This type of plant is one that lives predominantly in a wetland habitat, but it may survive in an upland habitat on occasion.

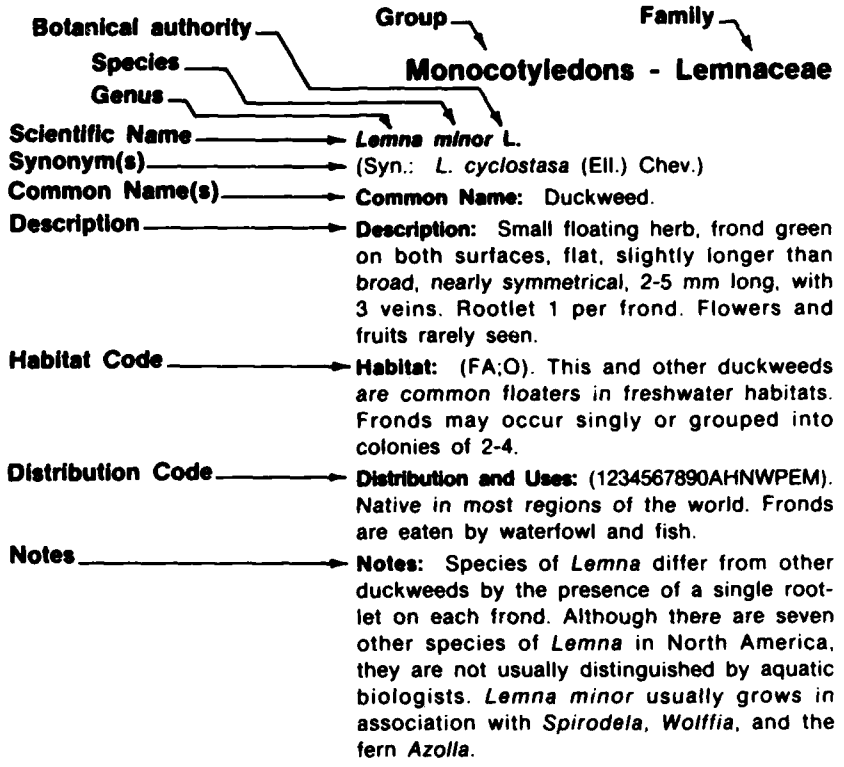
**O** - Obligate Wetland Plant. This type of plant is one that always lives in a wetland habitat.

A statement of precise habitat follows the habitat code.

Following the habitat is the distribution. The distribution in North America is coded, using the designations of the Soil Conservation Service (1982). (See map.) A statement of uses is given following the distribution. Other pertinent points are mentioned under notes.



## PLANT DESCRIPTION FORMAT:



## GLOSSARY FOR PLANT IDENTIFICATION

**achene** - a type of one-seeded, dry, indehiscent fruit

**adventitious** - buds or roots that develop without pattern in an unusual or irregular position

**alternate** - said of a leaf borne singly at each node

**annual** - living only 1 year

**axil** - the angle between any two organs or structures

**beaked** - having a short, terminal projection

**biennial** - life cycle completed in 2 years or seasons

**bladder** - small structures on submersed leaves which act as traps for capturing insect larvae

**bristle** - a stiff hair or hairlike growth

**calyx** - the usually green, outer whorl of the perianth, composed of sepals

**capsule** - a dry, dehiscent fruit that splits three or more ways at maturity

**catkin** - the flowering head of a cattail (*Typha* spp.). Also used to describe the flowers of some other plant species

**cordate** - with a sinus (space between two lobes) and rounded lobes at the base, usually ovate in general outline, heart-shaped

**corolla** - the inner, usually colored whorl of the perianth, composed of petals

**culm** - the specialized stem of grasses, sedges, and rushes

**cuticle** - a waxy, protective layer on the surfaces of the leaves and stems of plants

**dehiscent** - splitting open at maturity

**dicotyledon** - plants with two seed leaves (usually broadleaf plants)

**dioecious** - having the staminate and pistillate flowers on separate plants

**ellipsoid** - referring to a solid object that is broadest at the middle, gradually tapering to both ends

**elliptic** - broadest at the middle, gradually tapering to both ends

**emersed** - rising above the water surface

**entire** - a margin without teeth, lobes, or division

**fibrous** - referring to roots borne in tufts

**float** - an inflated stem

**frond** - the body of a fern

**herb** - a nonwoody plant

**indehiscent** - not splitting open at maturity

**inflorescence** - a cluster of flowers

**internode** - stem region between nodes

**lanceolate** - lance-shaped; broadest near base, gradually tapering to the narrower tip

**linear** - elongated and uniform in width throughout

**midrib** - main rib of normal leaf running from base to apex

**monocotyledon** - plants with one seed leaf and parallel veined leaves (usually grasses, sedges, rushes)

**monoecious** - having staminate and pistillate flowers on the same plant

**node** - that place on the stem from which leaves, branchlets, and adventitious roots arise

**oblanceolate** - reverse lance-shaped; broadest at apex, gradually tapering to a narrow base

**oblong** - broadest at the middle, and tapering to both ends, but broader than elliptic

**opposite** - said of two leaves borne across from each other at the same node

**ovate** - broadly rounded at base, becoming narrowed above; broader than lanceolate

**ovoid** - referring to a solid object that is broadly rounded at the base, becoming narrowed above

**palmate** - divided radically, like the fingers of a hand

**panicle** - a type of inflorescence composed of several racemes

**pendulous** - hanging downward

**perennial** - living for more than 2 years

**perianth** - a collective term for the corolla and calyx

**petal** - one unit of the corolla

**petiole** - leaf stalk

**pinnate** - divided once into distinct segments

**pistil** - the ovule-producing (female) part of the flower

**pistillate** - bearing the female parts of the flower

***prop root*** - a root produced near the base of the stem to give added support

**raceme** - a type of inflorescence where flowers with stalks are arranged along an elongated axis

**rachis** - a stalk bearing flowers or leaflets

**rhizomatous** - producing or possessing rhizomes

**rhizome** - an underground horizontal stem, bearing nodes, buds, and roots

**rootlet** - a small root

**rootstock** - subterranean stem

**rosette** - arrangement of leaves clustered symmetrically around the base of the stem

**sepal** - a single unit of the calyx

**serrate** -with sharp teeth pointing forward

**sessile** - without petioles, spikes, or stalks

**sheath** - tubular-type structure surrounding a plant part

**spathe** - a large sheathing leaflike structure surrounding or enclosing an inflorescence

**spike** - a type of inflorescence where flowers without stalks are arranged along an elongated axis

**spikelet** - a small spike

**spine** - a sharp-pointed outgrowth from a stem, leaf, or fruit

**spinulose** - bearing small spines

**spur** - a saclike extension of the flower

**stamen** - the pollen-producing (male) part of the flower

**staminate** - bearing the stamens, male parts of the flower (see pistillate)

**stolon** - a slender, horizontal stem, above or below the ground

**striations** - small lines or grooves

**submersed** - living below the surface of the water

**teeth** - any marginal protuberance, usually sharp-pointed

**tuber** - a short, thickened fleshy part of an underground stem. New plants develop from buds that grow in the axils of the minute scale leaves of a tuber

**tuft** - cluster of leaves or other elongate structures

**turion** - a winter bud that forms in the leaf axils of certain aquatic plants. When a plant matures, turions may drop onto bottom mud and produce new plants. Hydrilla plants produce turions

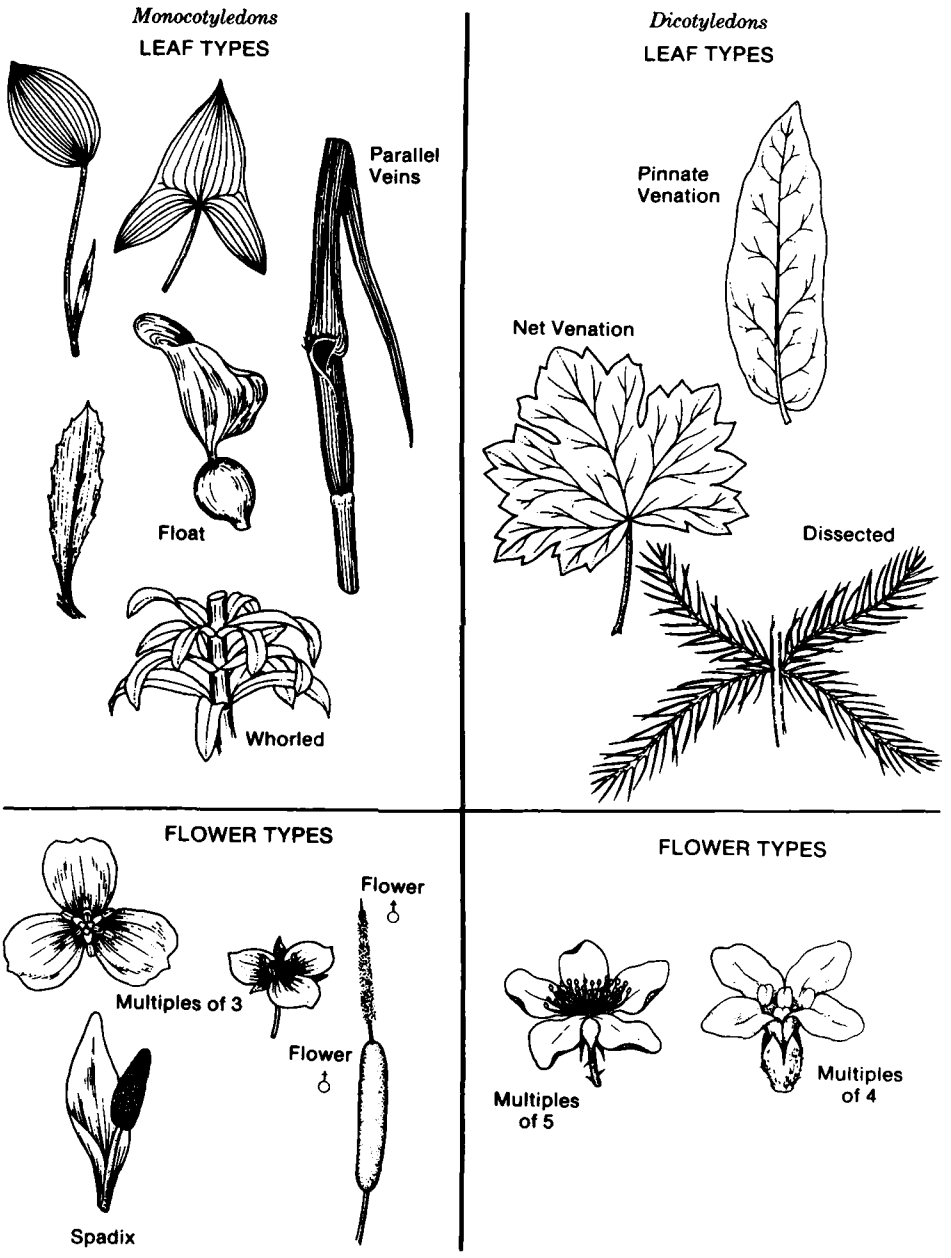
**umbel** - a type of inflorescence in which the flower stalks arise from the same level

**unisexual** - bearing either one sex or the other, but not both

**vein** - an elongated conducting structure visible on leaves

**whorl** - an arrangement of three or more structures at a node

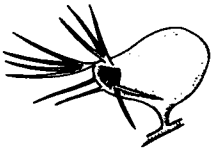
## ILLUSTRATED GLOSSARY




## ILLUSTRATED GLOSSARY

Rhizome

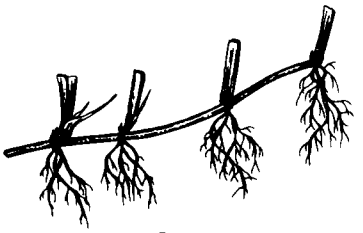
Tuber



Bladder in *Ultricularia*

Achene

Turion



Stolon

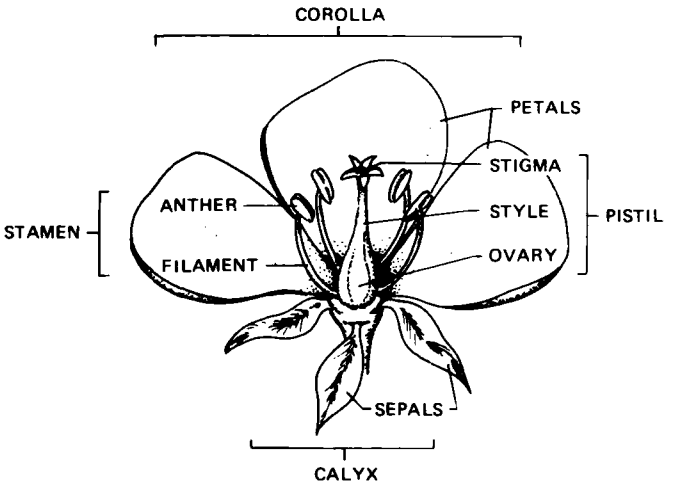
VEGETATIVE PARTS

Capsule

Berry

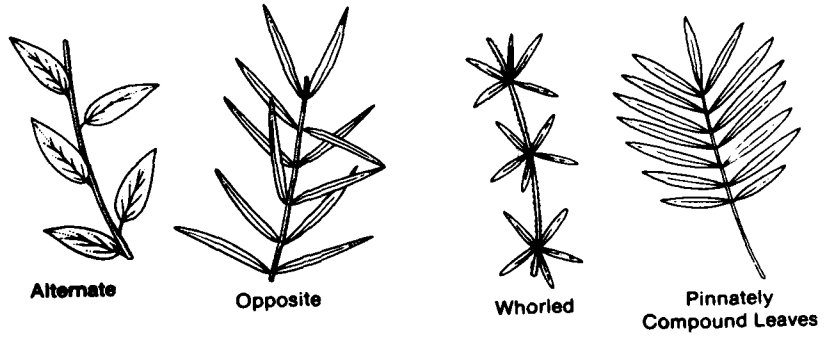
Nutlets

FRUIT TYPES

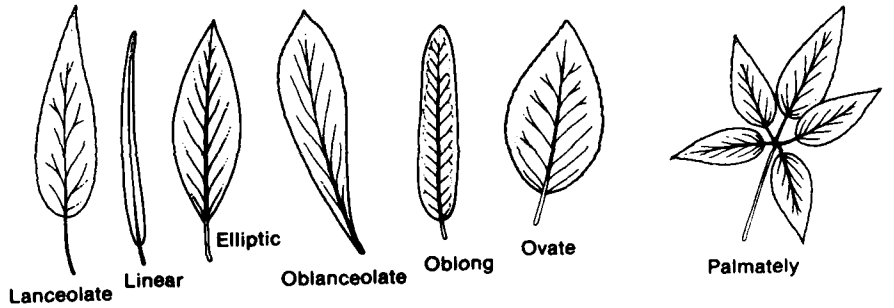



FLOWER PARTS

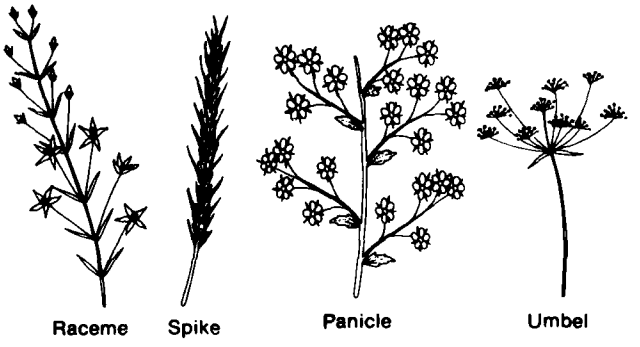
## ILLUSTRATED GLOSSARY




LEAF ARRANGEMENT




LEAF SHAPE




INFLORESCENCE TYPES

***Azolla caroliniana* Willd.**

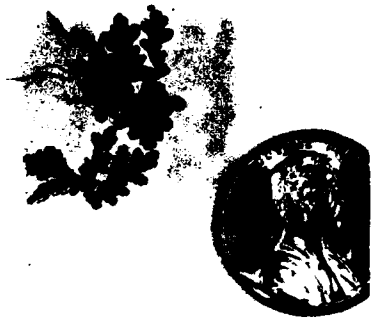
**Common Name:** Mosquito fern.

**Description:** Small, floating fern usually to 12 mm in diameter, often reddish in color. Leaves about 0.5 mm long. Reproductive structures visible only through a microscope.

**Habitat:** (FA;O). Standing water of ponds and swamps.

**Distribution and Uses:** (12368AC). Found in the eastern United States, the West Indies, and Brazil.

**Notes:** *Azolla mexicana* is similar but usually is slightly larger. It occurs in the western United States as well as the eastern. Both species of mosquito fern live in association with a variety of duckweed species. Blue-green algae inhabit the cells of both species of mosquito ferns. This relationship results in the fixation of nitrogen.



***Salvinia rotundifolia* Willd.**

**Common Name:** Salvinia.

**Description:** Floating fern with two kinds of leaves. Floating leaves 2, nearly spherical, blue-green, heart-shaped at base, hairy on both sides. Submersed leaf (frond) divided into threadlike divisions resembling roots. Reproductive structures formed at base of floating leaves.

**Habitat:** (FA;O). Ponds and canals high in organic matter.

**Distribution and Uses:** (2C). This fern is native to the Southern Hemisphere but has become introduced in much of the southern United States.

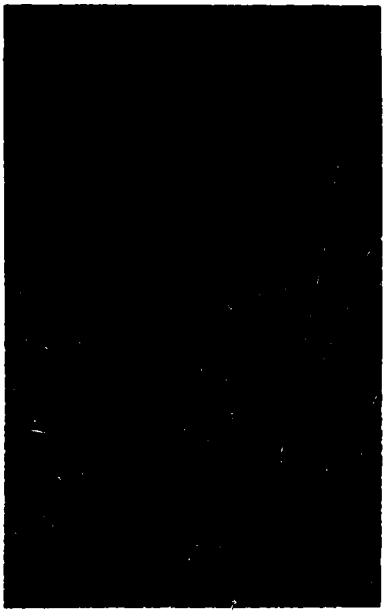
***Pistia stratiotes* L.**

**Common Name:** Waterlettuce.

**Description:** Biennial, floating, spongy-textured plant with a rosette of several leaves arranged to resemble a small head of lettuce, and with a tuft of roots. Leaves broadly rounded at upper end, margin without teeth, yellow-green, fine hairs on both surfaces and strongly veined. Flowers unisexual and inconspicuous, formed near the center of the rosette.

**Habitat:** (FA;O). Slow-moving streams and canals. This species can root in wet soil for a prolonged time.

**Distribution and Uses:** (2670C). Common only in Coastal Plain region from Florida to Texas.



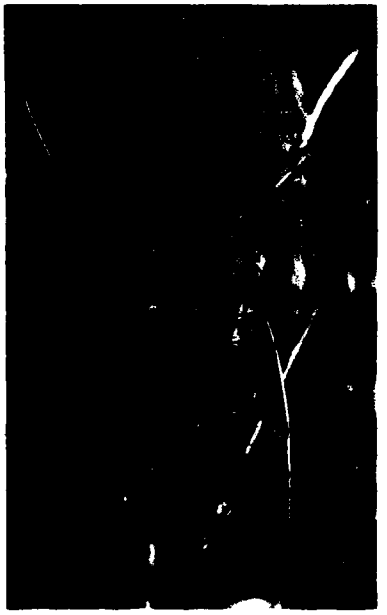
***Cladium jamaicense* Crantz**
(Syn.: *Mariscus jamaicensis* (Crantz) Britt.)

**Common Name:** Sawgrass.

**Description:** Erect perennial to 3 m tall, from stout rhizome. Leaves long and narrow, to 1.5 m long, to 1 cm broad, folded lengthwise, with numerous sharp teeth along the margins. Spikelets brown, 3-5 mm long, on pendulous branches. Achenes to 2.5 mm long.

**Habitat:** (FA;FM;O). This species grows in ponds, canals, and marshes.

**Distribution and Uses:** (126C). Sawgrass is found in the southeastern United States (a major component of the Florida Everglades), Central and South America, and the West Indies. The achenes are eaten by waterfowl.



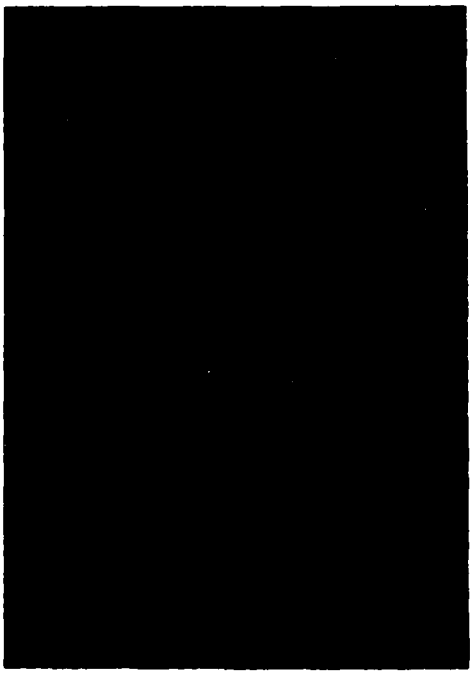
***Scirpus validus* Vahl.**

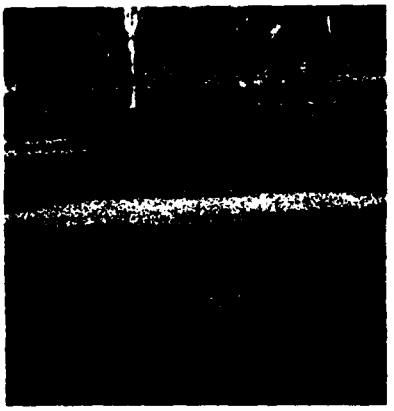
**Common Name:** Soft-stem bulrush.

**Description:** Creeping, robust perennial with smooth, soft, round, hollow stems to 3 m tall. Blades absent or to 10 cm long, often reduced to transparent sheaths at base of stem. Flowers in chestnut-colored ovoid spikelets in a drooping cluster a few centimeters from the tip of the stem, blooming from June to September.

**Habitat:** (FA;FM;O). In standing water or in marshes.

**Distribution and Uses:** (1234567890AH). Found throughout most of North America, this is one of the largest species in the genus. The fruits are eaten by waterfowl.





***Egeria densa* Planch.**
(Syn.: *Elodea densa* (Planch.) Vict.)

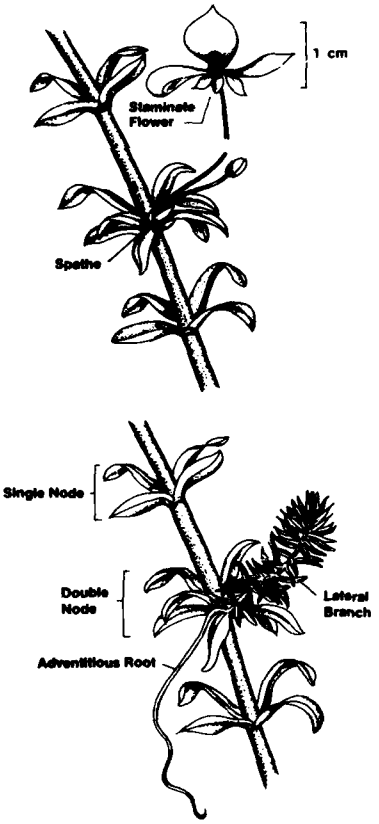
**Common Name:** Egeria; Brazilian elodea.

**Description:** Submersed rooted dioecious perennial with branched stems arising from rootcrowns. Leaves 4-6 in a whorl, very narrow, to 25 mm long and 2-5 mm broad, margins very finely toothed. Flowers white, blooming during the summer, raised above the water surface, 18-25 mm across, composed of 3 sepals and 3 petals; stamens 9 or 10. Fruit 7-8 mm long.

**Habitat:** (FA;O). Quiet water; slow-moving streams.

**Distribution and Uses:** (1256790). Native to South America but introduced into waters throughout the world. Ability to form dense mats. This is a popular aquarium plant.

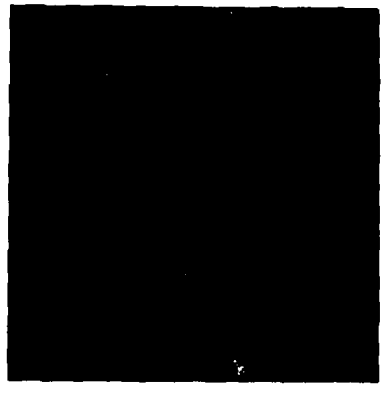
**Notes:** The similar genus *Elodea* has smaller flowers and only 3 leaves at a node. *Hydrilla*, another similar genus, has 3 stamens per flower. The midvein of each leaf of *Hydrilla* bears small spines, giving the leaves a rough feeling. Lateral buds, flowers, and adventitious roots occur at so-called "double nodes" in *Egeria*, further distinguishing it from *Elodea* and *Hydrilla*.




***Elodea canadensis* Rich.**

**Common Name:** Elodea; waterweed.

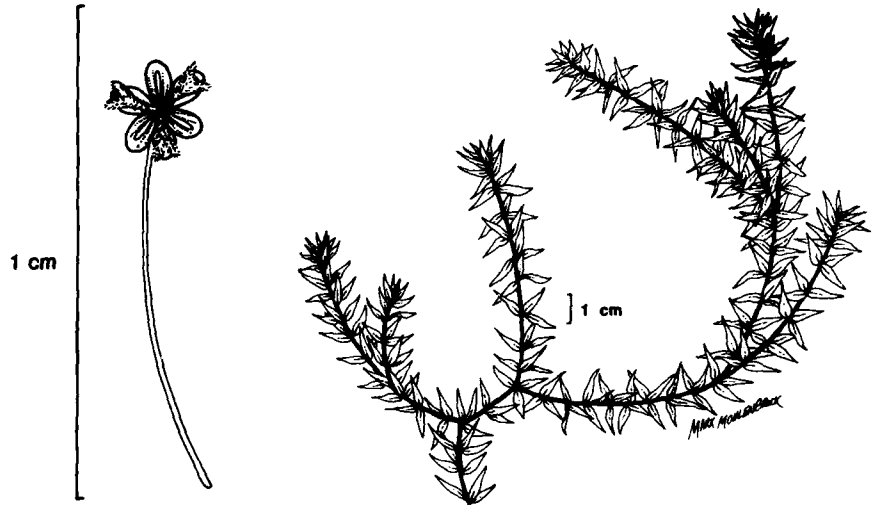
**Description:** Submersed dioecious perennial with branched stems. Leaves opposite or in whorls of 3; those of the staminate plants broadly lanceolate, to 13 mm long, to 5 mm broad; those of the pistillate plants linear to linear-lanceolate, to 10 mm long, to 3.5 mm broad. Flowers white, blooming during the summer, to 1 cm across, composed of 3 sepals and 3 white petals; stamens 9.

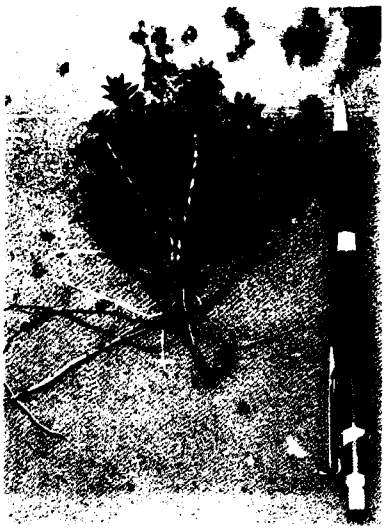


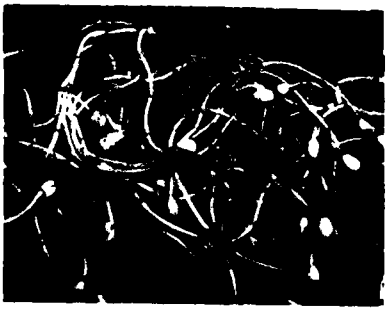
**Habitat:** (FA;O). Quiet water.

**Distribution and Uses:** (123456789WPEM). The attractive foliage makes this a popular aquarium plant This species is native to North America.

**Notes:** The similar genus *Elodea* has flowers at least 18 mm across and 4-6 leaves at each node. *Hydrilla* has only 3 stamens per flower. Staminate plants of *E. canadensis* are rarely seen. The leaves of *Elodea* are shorter than those of *Egeria* and lack the small spines on the lower midrib of *Hydrilla* leaves.







***Hydrilla verticillata* Royle**

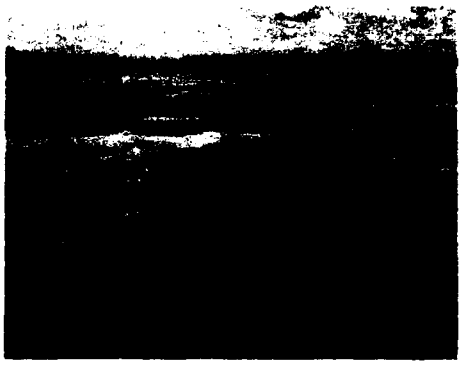
**Common Name:** Hydrilla.

**Description:** Submersed perennial with branched stems to 1 m long, and forming turions and tubers. Leaves whorled (3 to a node), to 15 mm long, to 4 mm broad, toothed, red-veined, spinulose on the lower surface. Flowers on long stalks, each flower 4-5 mm across, with 3 white petals.

**Habitat:** (FA;O). Most water habitats, often forming dense mats.

**Distribution and Uses:** (0126). Becoming abundant in most of the southern United States; also in Europe, Asia, Africa, and Australia.

**Notes:** Monoecious hydrilla is similar in appearance to the dioecious variety. The range of monoecious hydrilla includes the mid-Atlantic states. This biotype is found spreading laterally along the bottom. Canopy formation is rare. Within its range, monoecious hydrilla regrows each spring from tubers and turions. May be confused with *Egeria* or *Elodea*.



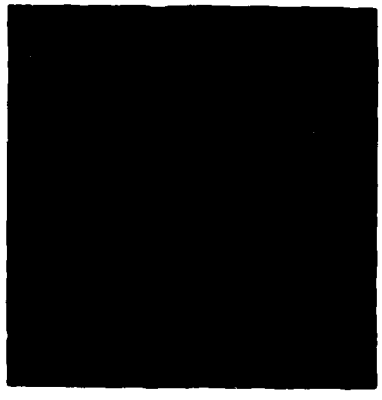
***Vallisneria americana* Michx.**

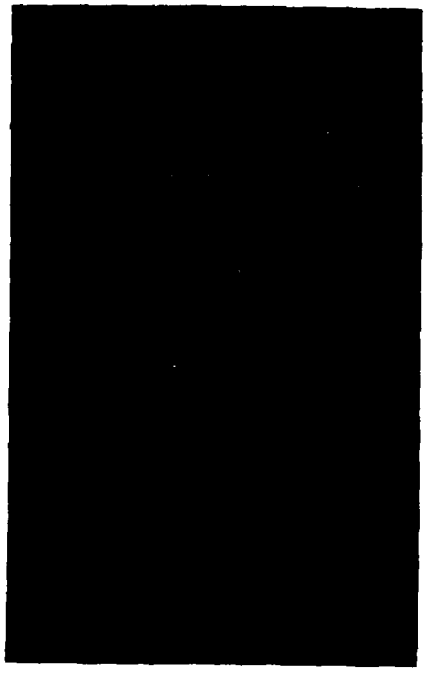
**Common Name:** Wildcelery; tapegrass.

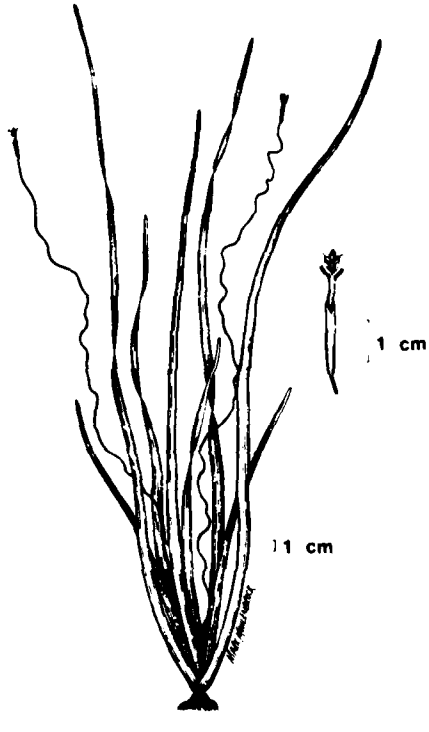
**Description:** Dioecious submersed perennial arising from stoloniferous rootstocks with fibrous roots. Leaves ribbon-shaped, to 2 m long or longer, to 3 cm broad, the tips sometimes floating on the water. Staminate flowers, produced at base of plant, break loose and float to surface of water. Pistillate flowers on long stalks. Fruits on long, spiral-shaped stalks, ripening under water.

**Habitat:** (FA;O). Lakes and streams.

**Distribution and Uses:** (123456789PEM). Throughout most of the United States, but most abundant in the East and Midwest. Wildcelery is a primary source of food for waterfowl, particularly diving ducks.

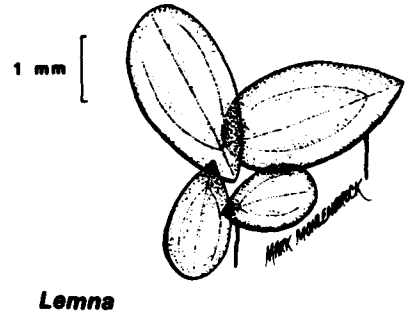




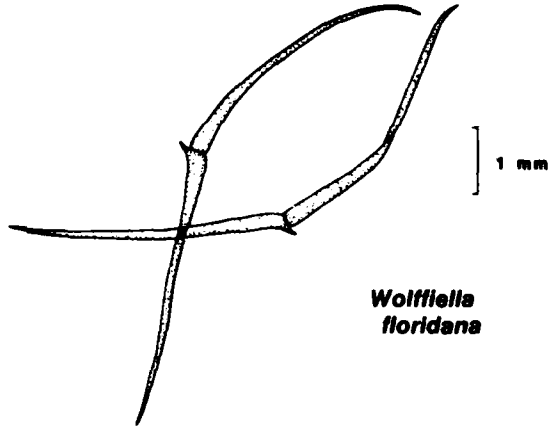


## **Monocotyledons** - LEMNACEAE - Duckweeds

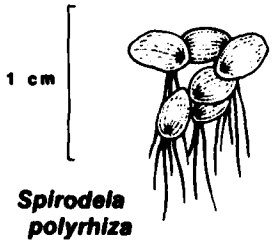
Duckweeds are small, floating freshwater herbs found in most parts of the world. Four genera and approximately 17 species of duckweeds occur in North America. Duckweeds are flowering plants, but their minute flowers are infrequently produced and rarely seen by the casual observer. The body of the plant is referred to as the frond.



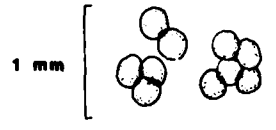

***Lemna minor***




***Wolffiella floridana***




***Spirodela polyrhiza***




***Wolffia columbiana***

***Lemna minor* L.**
(Syn.: *L. cyclostasa* (Ell.) Chev.)

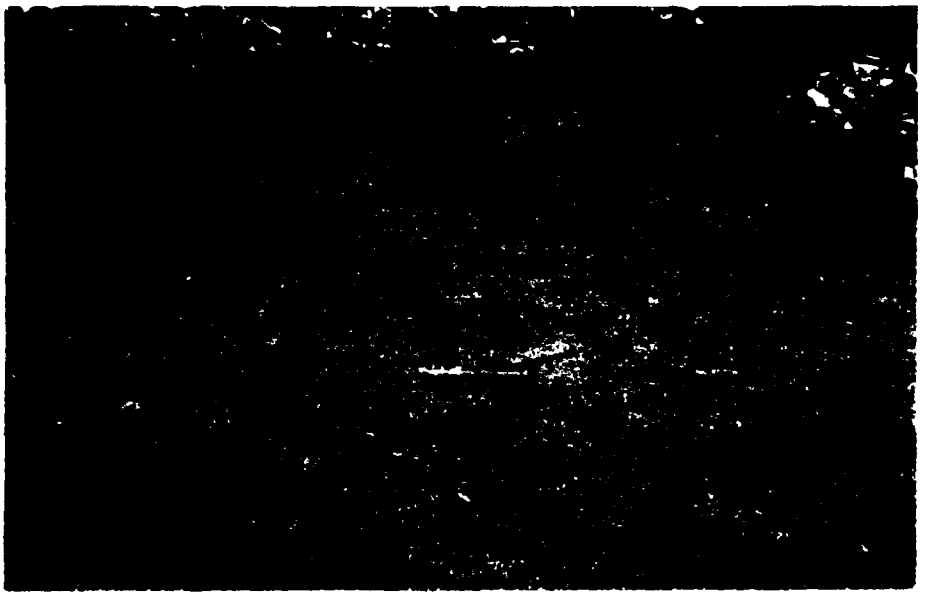
**Common Name:** Duckweed.

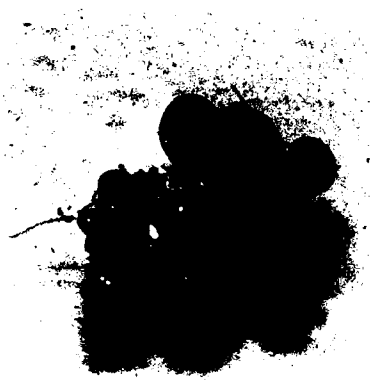
**Description:** Small floating herb, frond green on both surfaces, flat, slightly longer than broad, nearly symmetrical, 2-5 mm long, with 3 veins. Rootlet 1 per frond. Flowers and fruits rarely seen.

**Habitat:** (FA;O). This and other duckweeds are common floaters in freshwater habitats. Fronds may occur singly or grouped into colonies of 2-4.

**Distribution and Uses:** (1234567890AHNWPEM). Native in most regions of the world. Fronds are eaten by waterfowl and fish.

**Notes:** Species of *Lemna* differ from other duckweeds by the presence of a single rootlet on each frond. Although there are seven other species of *Lemna* in North America, they are not usually distinguished by aquatic biologists. *Lemna minor* usually grows in association with *Spirodela*, *Wolffia*, and the fern *Azolla*.





***Spirodela polyrhiza* (L.) Schleid.**

**Common Name:** Giant duckweed; greater duckweed.

**Description:** Small floating herb, frond green on the upper surface and purple on the lower surface, flat, spherical to sometimes longer than broad, asymmetrical, 2-7 mm long, with 5-8 veins. Rootlets 2-10 per frond. Flowers and fruits rarely seen.

**Habitat:** (FA;O). *Spirodela polyrhiza* is abundant in lakes, ponds, and freshwater swamps where it can completely obscure the surface of the water. Fronds are often grouped into colonies.

**Distribution and Uses:** (1234567890HCNWPEM). This species is found throughout much of the world. Giant duckweed is utilized to some extent as food by waterfowl.

**Notes:** The purple color on the lower surface is characteristic of *Spirodela* and distinguishes it from other duckweeds. Species of *Spirodela* have 2-10 rootlets per frond and are generally larger than species of *Lemna*. One other greater duckweed in North America, *S. punctata* (Mey.) C.H. Thompson (syn.: S. *oligorhiza* (Kurz) Hegelm.), has obscure veins and usually fewer rootlets. Species of *Spirodela* usually grow in association with species of *Lemna*, *Wolffia*, and the fern *Azolla*.

***Wolffia columbiana* Karst**

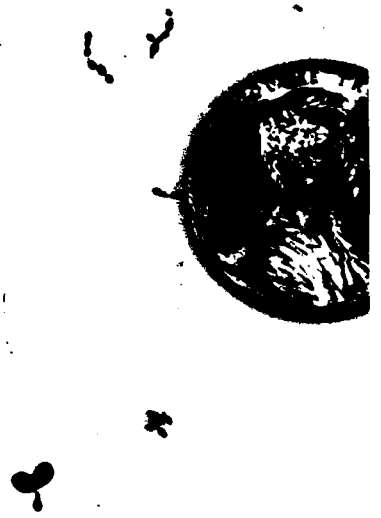
**Common Name:** Watermeal.

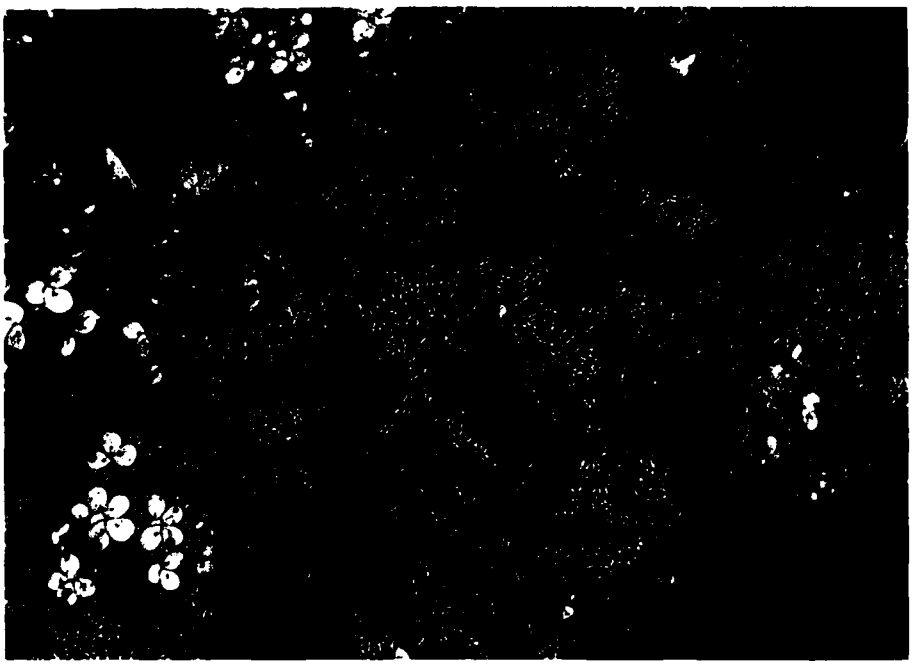
**Description:** Very small floating herb, frond green, spherical, thick, to 1.2 mm in diameter, without veins. Rootlets absent. Flowers and fruits rarely seen.

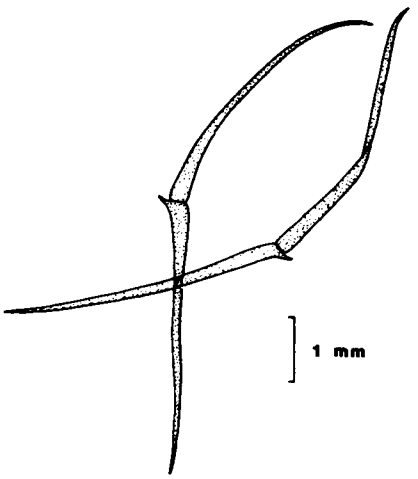
**Habitat:** (FA;O). *Wolffia columbiana* is a frequent species of lakes, ponds, and swamps. It may occur in such abundance as to obscure the surface of the water.

**Distribution and Uses:** (12345690HE). This species is common in North, Central, and South America. It provides a source of food for waterfowl and fish.

**Notes:** Species of *Wolffia* lack rootlets and have more or less spherical fronds. They almost invariably grow with other duckweeds.








***Wolffiella floridana* (J.D.Sm.) C.H. Thompson**

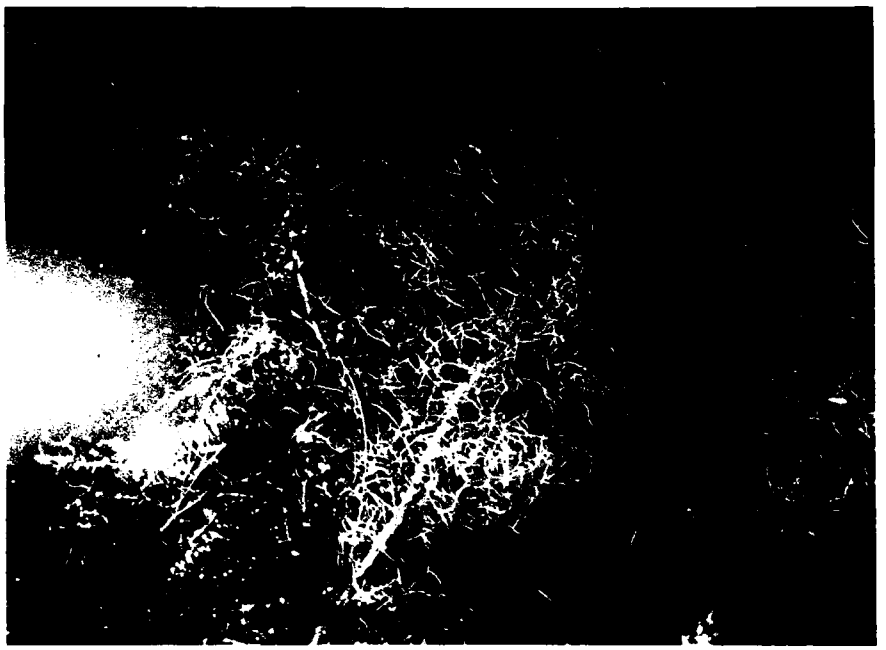
**Common Name:** Slender duckweed; wolffiella.

**Description:** Small floating herb, fronds green, very narrow, pointed or rounded at the tips, 3-12 mm long, to 1 mm broad, without veins. Rootlets absent. Flowers and fruits rarely seen.

**Habitat:** (FA;O). This species occurs in standing water where it often congregates into star-shaped colonies.

**Distribution and Uses:** (12369). This species is not known outside the United States. It is a source of food for waterfowl and fish.

**Notes:** *Wolffiella* is distinguished by its absence of rootlets and its strap-shaped fronds. It usually grows in association with other kinds of duckweeds.



***Najas guadalupensis* (Spreng.) Magnus**

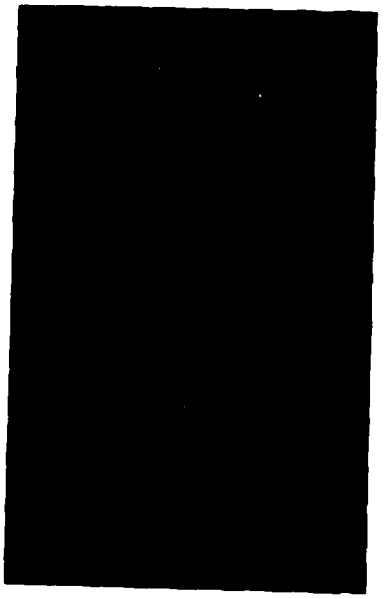
**Common Name:** Southern naiad.

**Description:** Very slender submersed annual with usually sparsely branched stems. Leaves very narrow, often nearly threadlike, several at each node, to 2 cm long, to 1.2 mm broad, with microscopic teeth along the margins. Flowers minute in the axils of the leaves, blooming during the summer. Fruits slender, nearly straight, beaked, 1.2-2.4 mm long, with 16-24 rows of usually rectangular markings.

**Habitat:** (FA;O). Lakes, ponds, canals, freshwater estuaries. This species can tolerate some salinity.

**Distribution and Uses:** (1234567890CE). This species also occurs in tropical America. All parts of the plant are eaten by waterfowl.

**Note:** The leaves are sometimes purplish.



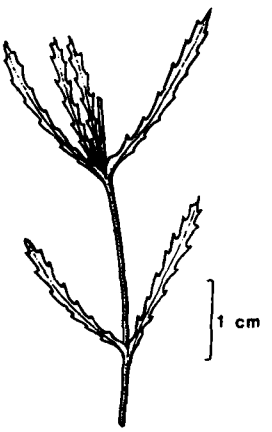
***Najas marina* L.**

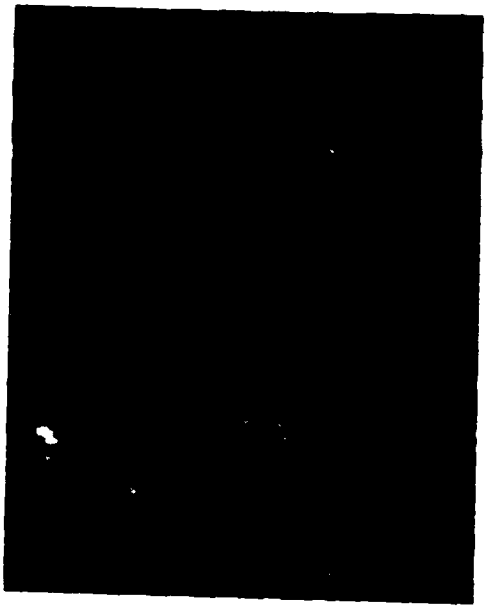
**Common Name:** Marine naiad; toothed naiad.

**Description:** Slender, submersed, dioecious annual. Leaves linear to linear-oblong, several at each node, to 3 cm long, 0.8-2.5 mm broad, with 3-12 conspicuous teeth along each margin. Flowers 3-4 mm long in the axils of the leaves, blooming during the summer. Fruits ellipsoid, beaked, 4-9 mm long, the surface pitted.

**Habitat:** (FA;MA;O). Brackish lakes and ponds, often in deep water.

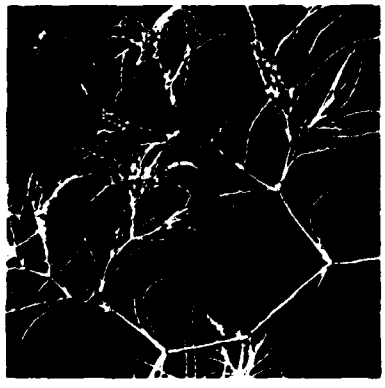
**Distribution and Uses:** (123467890C). In addition to being scattered in the United States, this species occurs in the tropics, Europe, and Asia. All parts of the plant are consumed by waterfowl.



***Najas minor* All.**

**Common Name:** Slender naiad, spiny-leaf naiad.



**Description:** Slender, submersed, annual with much-branched stems. Leaves very narrow, several at each node, to 3.5 cm long, 0.2-0.3 mm wide, with tiny teeth along the margins. Flowers minute in the axils of the leaves, blooming during the summer. Fruits slender, slightly curved, 2.5-3.5 mm long, with 10-18 vertical rows of striations.

**Habitat:** (FA;O). Lakes and ponds.

**Distribution and Uses:** (123). Found in the eastern United States, Europe, and Asia. The entire plant is eaten by waterfowl, especially diving ducks. *Najas minor* may be confused with the alga *Chara*. *Chara* has a strong garlic odor when crushed; *N. minor* does not.

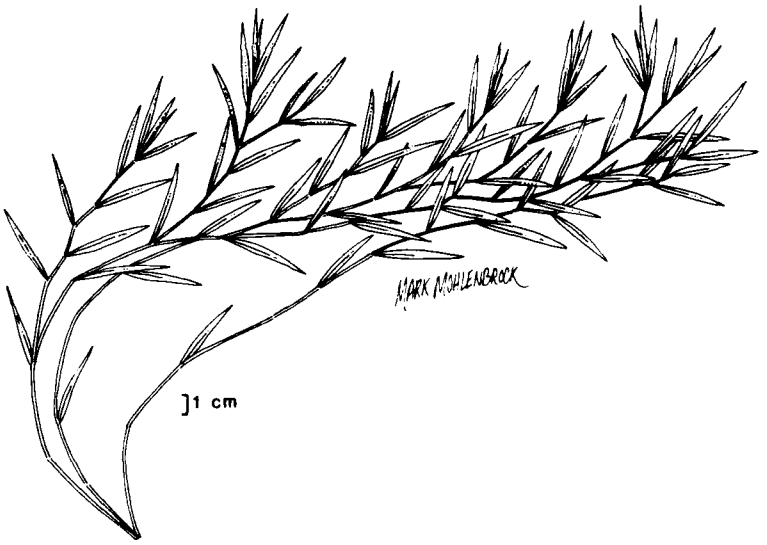
***Hydrochloa caroliniensis* Beauv.**

**Common Name:** Southern watergrass.

**Description:** Submersed and emersed perennial rooted beneath shallow water. Stems branched, to 1 m long, floating on the water or ascending above it. Leaves short, only to 3 cm long, to 4 mm broad. Spikelets unisexual, the staminate terminal, the pistillate borne in the leaf axils.

**Habitat:** (FA;FS;O). This species grows in a variety of aquatic habitats in water to 2 m deep. It also occurs in swamps.

**Distribution and Uses:** (26). Confined from the coast of North Carolina around to Texas. The leaves and fruits are used for food by waterfowl.



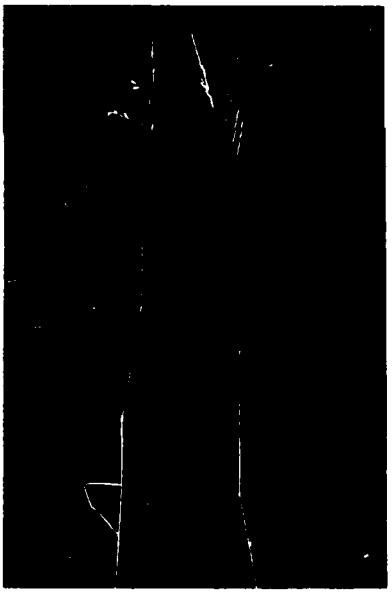
***Leersia hexandra* Sw.**

**Common Name:** Cutgrass.

**Description:** Perennial; stems rooting at the nodes, becoming upright, to 1 m tall, smooth except for hairy nodes. Leaves to 18 cm long, to 5 mm broad, usually smooth except for the sharp, fine teeth along the margins. Panicles narrow, to 10 cm long, with each branch bearing spikelets nearly to the base; spikelets 4-5 mm long, to 2 mm broad.

**Habitat:** (FA;FM;O). Standing water, shores, swamps, sometimes forming large floating mats.

**Distribution and Uses:** (1260). This grass, abundant in the tropics, is confined in the United States to the Southeast. The seeds are eaten by waterfowl.




***Panicum hemitomon* Schult.**

**Common Name:** Maidencane.

**Description:** Aquatic or wet soil perennial with intertwining rhizomes. Stems to 1.5 m tall, smooth. Leaves to 25 cm long, to 1.5 cm broad, rough along the margins. Spikelets arranged in a panicle to 20 cm long, each spikelet about 2.5 mm long.

**Habitat:** (FA;FM;FS;O). Lakes and ponds, in water to 2 m deep. Also in wet soil.

**Distribution and Uses:** (126). Southeastern United States and South America. Its dense growth provides excellent cover for fish.

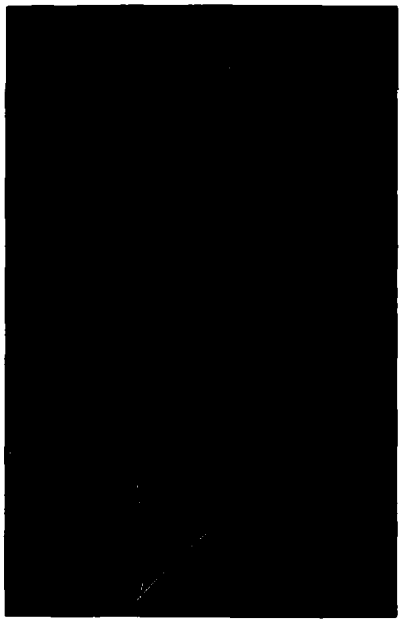
***Panicum purpurascens* Raddi**
(Syn.: *Brachiaria purpurascens* (Raddi) Henr.)

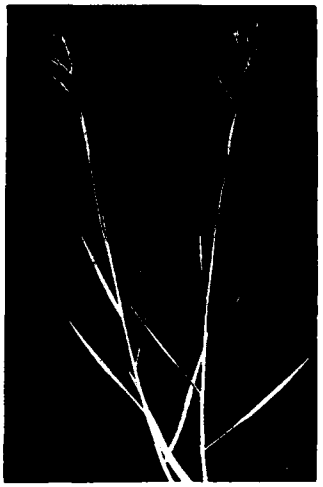
**Common Name:** Paragrass.

**Description:** Erect perennial grass with horizontal stolons and stems rooting near base. Stems eventually ascending, up to 1 m tall, densely hairy on the nodes. Leaves up to 35 cm long, up to 1.5 cm broad, hairy on both surfaces. Spikelets borne in panicles up to 25 cm long, each spikelet about 3 mm long, usually purplish.

**Habitat:** (FM;F). Wet, usually disturbed soil, but capable of growing from the shore into the water, forming dense floating mats.

**Distribution and Uses:** (26). This tropical native is spreading from Florida to Texas. Seeds are used as a secondary food source by waterfowl.





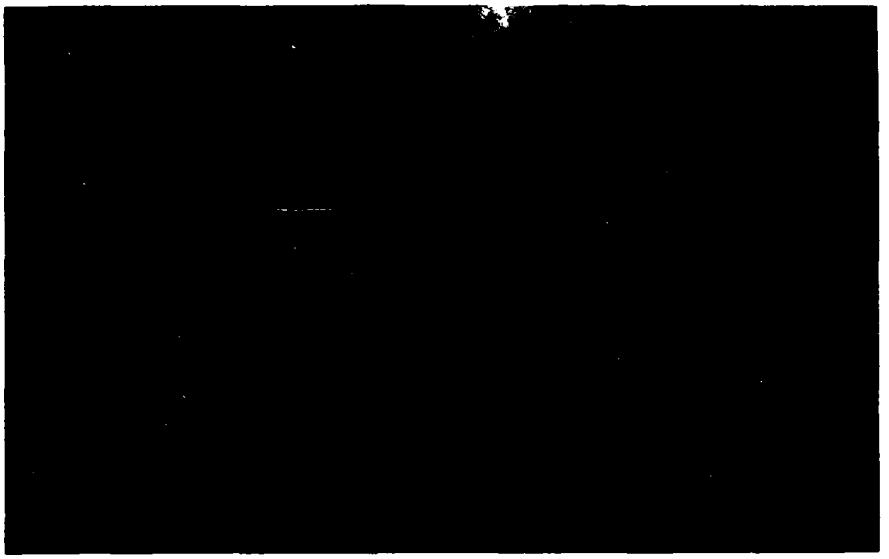
***Panicum repens* L.**

**Common Name:** Torpedograss.

**Description:** Perennial from stout rhizomes. Stems upright, stiff, to 75 cm tall. Leaves long, narrow, pointed, to 7 mm broad, with a hairy sheath. Spikelets ovate, 2.0-2.5 mm long, sometimes purplish, borne in a panicle to 12 cm long.

**Habitat:** (FA;FM;F). Torpedograss grows abundantly along the banks of canals, often entering the water and forming floating mats.

**Distribution and Uses:** (26V). Native to Australia, this species has invaded areas from Florida to Texas and in Central and South America.



***Paspalum fluitans* (Ell.) Kunth**

***Common Name:*** *Water paspalum.*

**Description:** Annual; stems tufted, soft and spongy, usually sprawling, to 2 m long. Leaves to 25 cm long, to 2.5 cm broad, margins smooth or rough, with hairy sheaths. Spikelets borne in 5-50 racemes on one side of a flat, broad rachis, each spikelet 1.2-1.7 mm long, hairy.

**Habitat:** (FA;FS;O). Water paspalum may grow in shallow water or on muddy soil.

**Distribution and Uses:** (12356). Mostly confined to the southeastern United States.

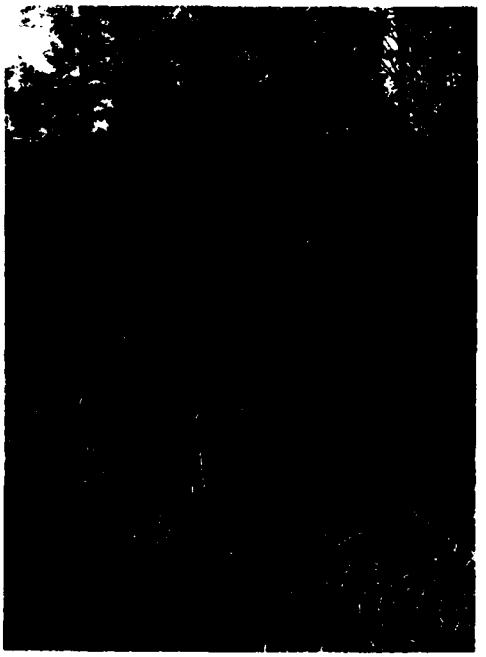
***Phragmites australis* (Cav.) Trin.**
(Syn.: *P. cummunis* (L.) Trin.)

**Common Name:** Common reed.

**Description:** Erect, tall perennial from stout, creeping rhizomes. Stems to 4 m tall. Leaves flat, smooth on the surface, to 5 cm broad. Inflorescence large, 15-40 cm long, yellow to purple, consisting of many 3- to 7-flowered spikelets, blooming from July to September.

**Habitat:** (FM;O). This species is abundant in some marshy habitats, often forming very extensive colonies. It is also capable of establishing in soil with a high water table.

**Distribution and Uses:** (1234567890NWPEM). This species is found in most parts of the world. This coarse grass provides cover and roosting sites for birds.

***Setaria magna* Griseb.**

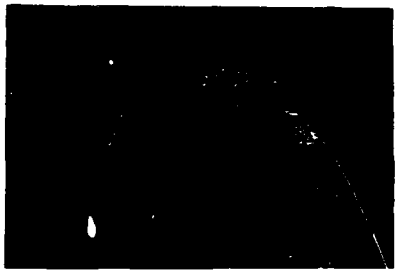
**Common Name:** Giant foxtail.

**Description:** Erect, coarse annual, usually with prop roots. Stems to 4 m tall. Leaves to 50 cm long, to 5 cm broad, rough to the touch. Spikelets borne in a dense cylindrical panicle to 30 cm long, often pendulous, each spikelet about 2 mm long, subtended by bristles.

**Habitat:** (FA;FM;F). In water and along banks of lakes and ponds; marshes; drainage canals; ditches.

**Distribution and Uses:** (126C). Coastal Plain from New Jersey around to Texas. Also in the West Indies and Central America. The seeds are eaten by game birds and songbirds.

**Note:** This species closely resembles napier grass (*Pennisetum purpureum*).



***Zizaniopsis miliacea* (Michx.) Doell. & Asch.**

**Common Name:** Giant cutgrass.

**Description:** Erect perennial grass with stems to 4 m high. Leaves long, narrow, flat, to 1 m long, tp 3 cm broad, smooth on the surface, rough on the margins. Spikelets numerous in panicles to 60 cm long, the pistillate flowers borne in spikelets in the upper half of the panicle and the staminate flowers borne in spikelets in the lower half of the panicle; spikelets 5-8 mm long.

**Habitat:** (FWM;FWS;O). This species grows in standing water or in wet soil of marshes and swamps, along edges of lakes, rivers, and creeks, often forming dense colonies.

**Distribution and Uses:** (1236). Giant cutgrass grows primarily in the southern United States. It provides cover for waterfowl.

**Note:** This species is often confused with wild rice (*Zizania aquatica*).

***Eichhornia crassipes* (Mart.) Solms**

**Common Name:** Waterhyacinth.

**Description:** Floating perennial, rooting at the nodes. Leaves broadly elliptic to nearly round, to 20 cm long, to 15 cm broad, with long spongy petioles usually inflated at the base. Flowers borne in racemes, blue-purple with a yellow spot, 4-6 cm long, the perianth united and funnel-shaped; stamens 6. Fruit a many-seeded capsule.

**Habitat:** (FA;FM;O). Streams, ponds, waterways, ditches, backwater areas.

**Distribution and Uses:** (12360HC). This species, native to South America, is an aggressive weed in the warmer parts of the United States where it clogs waterways. It does, however, absorb some pollutants in the water and has been utilized in municipal water treatment facilities. It spreads primarily by means of horizontal stolons.

***Pontederia cordata* L.**
(Syn.: *P. lancifolia* (Muhl.) Torr.)

**Common Name:** Pickerelweed.

**Description:** Emersed, stout perennial. Leaves ovate to lanceolate, heart-shaped at the base, to 20 cm long. Flowers 12-17 mm long, blue-purple, asymmetrical, crowded in elongated terminal spikes, each flower with 6 petal-like parts united below into a tube, blooming from May to September. Fruits beaked.

**Habitat:** (FA;FS;O). Standing water or edges of swamps.

**Distribution and Uses:** (1236EM). Found in the eastern half of North America. The seeds are eaten by waterfowl as a secondary food source.

**Note:** There is considerable variation in the shape of the leaves.

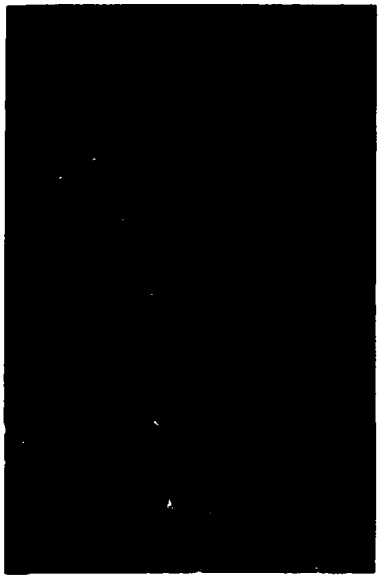

***Potamogeton crispus* L.**

**Common Name:** Curlyleaf pondweed.

**Description:** Submersed perennial with rhizomes. Stems branched, somewhat flattened. Leaves reddish green, alternate, oblong, wavy along the margins, finely toothed, to 8 cm long, to 1 cm broad. Flowers borne in short cylindrical terminal spikes during the summer. Fruits ovoid, beaked, to 7 mm long, green or brown.

**Habitat:** (FA;O). Ponds, lakes, streams.

**Distribution and Uses:** (1234567890WEM). Introduced into North America where it now occurs throughout most of the continent. The fruits are eaten by waterfowl.

***Potamogeton illinoensis* Morong**

**Common Name:** Illinois pondweed.

**Description:** Perennial, submersed plant with extensive rhizomes and branched stems. Floating leaves elliptic to lanceolate, to 15 cm long and 6 cm broad, on petioles 5-8 cm long. Submersed leaves similar, but on petioles less than 5 cm long. Flowers inconspicuous on cylindrical spikes to 8 cm long, emerging above the water. Nutlets to 4 mm broad.

**Habitat:** (FA;O). Found in almost any type of freshwater.

**Distribution and Uses:** (1234567890NWPEM). Throughout most of the United States. The plant provides food and cover for aquatic organisms.

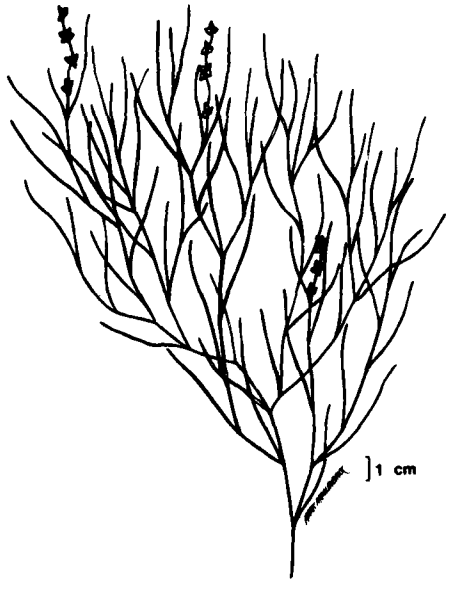
***Potamogeton pectinatus* L.**

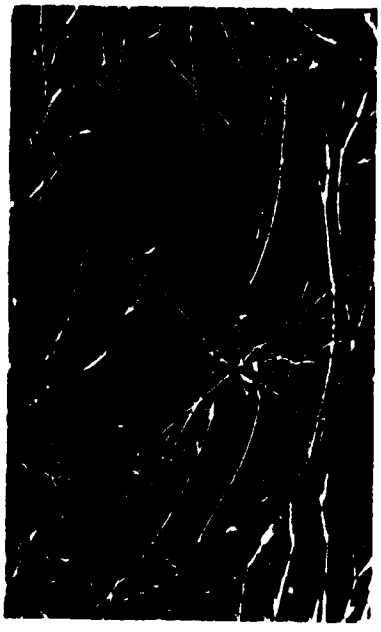
**Common Name:** Sago pondweed.

**Description:** Perennial, submersed plant with slender, branched stems and creeping rhizomes. Leaves long and narrow, to 30 cm long, to 1.5 mm broad, without teeth. Flowers borne in whorls in a slender spike to 5 mm long, inconspicuous, greenish. Nutlets to 4.5 mm long.

**Habitat:** (FA;MA;O). Ponds and streams in fresh, saline, and brackish waters.

**Distribution and Uses:** (1234567890AHNWPEM). This species is found in most parts of the world. Most of the plant is eaten by waterfowl.





***Ruppia maritima* L.**

**Common Name:** Widgeongrass.

**Description:** Submersed, rhizomatous perennial with much-branched stems. Leaves alternate, threadlike, the margins without teeth, to 10 cm long, dilated at base into a sheath to 1 cm long. Flowers inconspicuous, borne in pairs from the leaf sheath. Fruits fleshy, 4-6 together, each to 3 mm long, borne on a slender stalk to 6 cm long.

**Habitat:** (MA;O). This species occurs mainly in saline or brackish waters of ponds and canals and in estuaries.

**Distribution and Uses:** (123456890ACWPEM). Widespread in North America and Europe. Much of the plant is eaten by waterfowl.

***Typha* spp. L.**

**Common Name:** Cattail.

**Description:** Erect, robust perennial with creeping rhizomes. Stems to 4 m tall, unbranched. Leaves elongated, flat, usually 8 or more per plant, to 25 mm broad. Staminate flowers in a slender stalk above the thicker pistillate spike, both the staminate and pistillate flowers small and without sepals or petals, blooming during the summer. Fruits tiny, surrounded by numerous white hairs. Four species of *Typha* are found in the United States: *T. glauca, T. angustifolia, T. domingensis,* and *T. latifolia.*

**Habitat:** (FS;O). This species is abundant in densely saturated habitats, but is not common in standing water.

**Distribution:** (1234567890AHNWPEM). Found throughout most of North America, Europe, and Asia. The starchy rhizomes, the young flowering spikes, and the pollen are edible.

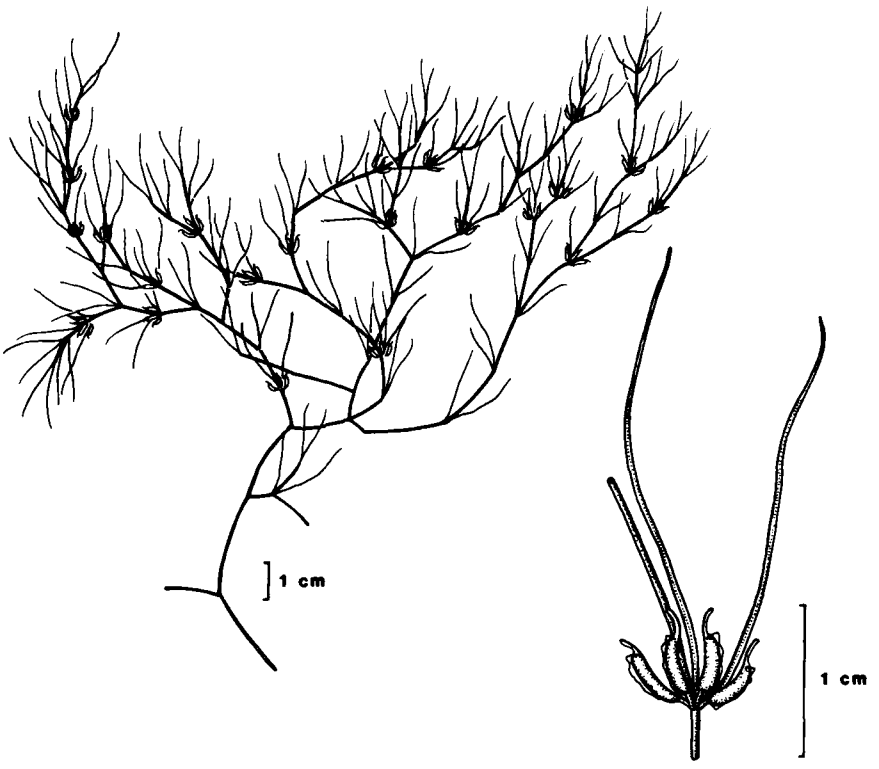
***Zannichellia palustris* L.**

**Common Name:** Horned pondweed.

**Description:** Submersed, rhizomatous perennial with branched, slender stems. Leaves opposite, long and threadlike, without teeth, to 3 cm long. Flowers unisexual, inconspicuous in the axils of the leaves. Fruits are achenes, flat, 2-3 mm long with a terminal beak 1.0-1.5 mm long.

**Habitat:** (FA;O). Fresh or brackish water to 2 m deep.

**Distribution and Uses:** (1234567890ANWPEM). Horned pondweed is found in most parts of the world. The fruits are eaten by waterfowl.



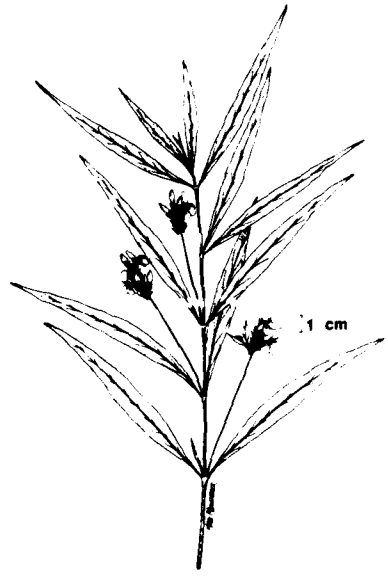
***Justicia americana* (L.) Vahl**
(Syn.: *Dianthera americana* L.)

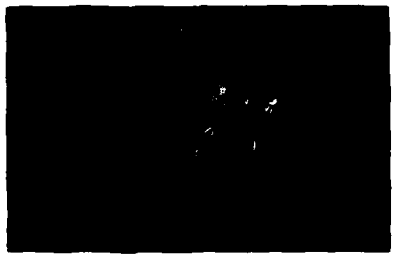
**Common Name:** Waterwillow.

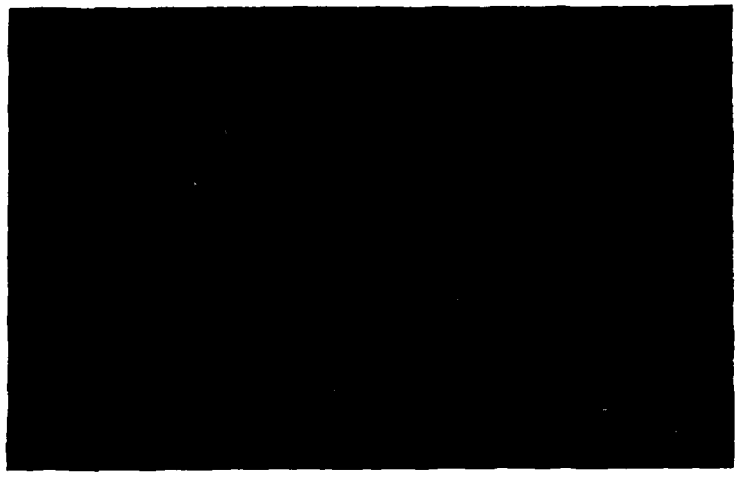
**Description:** Perennial, emersed herb spreading by rhizomes. Stems usually unbranched, smooth, to 1 m tall. Leaves opposite, simple, lanceolate, the margins without teeth, smooth, tapering to each end. Flowers borne in spikes 1-3 cm long on long stalks from the axils of the leaves, each flower purple and white, composed of an asymmetrical, 5-lobed corolla, blooming from June to August.

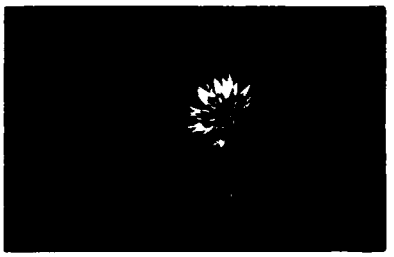
**Habitat:** (FA;FS;O). Running water or in mud.

**Distribution and Uses:** (12356E). This species is confined to eastern North America.







***Alternanthera philoxeroides* (Mart.) Griseb.**

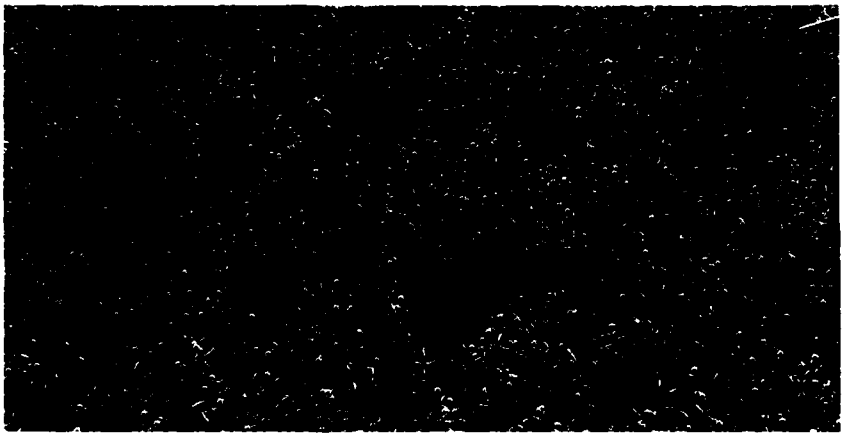
**Common Name:** Alligatorweed.

**Description:** Emersed or submersed perennial. Stems smooth, the main ones trailing on the ground and forming mats. Flowering stems upright to several centimeters tall. Leaves entire, opposite, simple, elliptic to oblanceolate, to 10 cm long. Flowers borne from axils of the leaves in spikes to 1 cm long. Each flower with 5 free white sepals, blooming from April through October.

**Habitat:** (FA;FS;FM;O). In water or very wet soil, often forming dense floating mats; sometimes in brackish water.

**Distribution and Uses:** (126). Abundant in the southeastern coastal states from Virginia around to Texas. Native of South America.

**Notes:** The aquatic form of alligatorweed usually has hollow stems, whereas the terrestrial form does not. Another species, *A. polygonoides* (L.) R. Brown, has broader leaves and flowers that are sessile in the leaf axils.



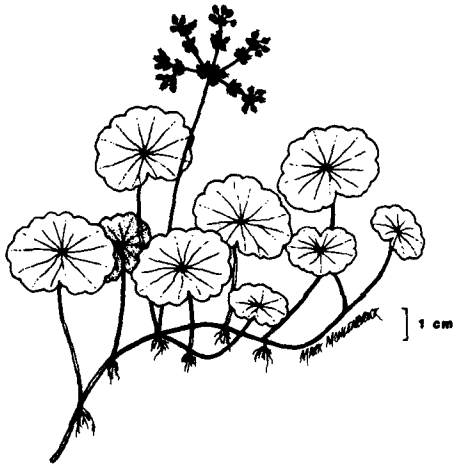
***Hydrocotyle umbellata* L.**

**Common Name:** Water pennywort.

**Description:** Perennial; stems floating in water or creeping on wet soil, smooth, rooting at the nodes. Leaves round, to 7 cm in diameter, with low, rounded lobes, attached at its center by a petiole, to 25 cm long. Flowers crowded into umbels, each umbel on a smooth stalk usually longer than the petiole. Petals 5, white, very small.

**Habitat:** (FA;FM;O). In and around ponds and canals, rooted in the mud, sometimes forming dense mats.

**Distribution and Uses:** (1236790CWM). Found in much of the eastern half of the United States as well as in tropical South America.




***Brasenia schreberi* J.F. Gmel.**

**Common Name:** Watershield.

**Description:** Floating-leaved perennial with elongated stems arising from creeping root-stocks and covered with a thick gelatinous coating. Leaves floating on the surface of the water, green on the upper surface, purple and very gelatinous on the lower surface, elliptical, to 12 cm long and to 6 cm broad, attached at the center by the petiole. Flowers rose-purple, solitary from the upper leaf axils, with 3 sepals and 3 petals up to 15 mm long. Fruit small and leathery.

**Habitat:** (FA;O). Standing water of ponds, lakes, and swamps.

**Distribution and Uses:** (1235690AWPEM). Found worldwide. This species may be grown as an ornamental in home ponds. The fruits are eaten by waterfowl. It is a particularly good source of food for ring-necked ducks.

**Note:** There are no other members of this genus in the world.

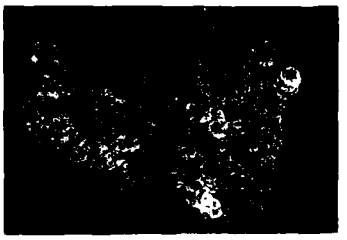
***Cabomba caroliniana* Gray**

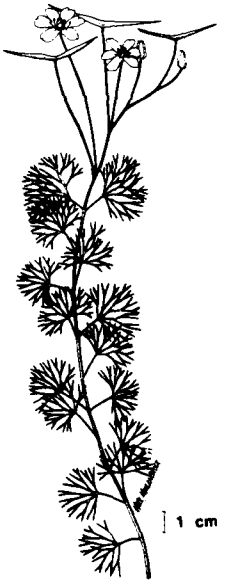
**Common Name:** Fanwort.

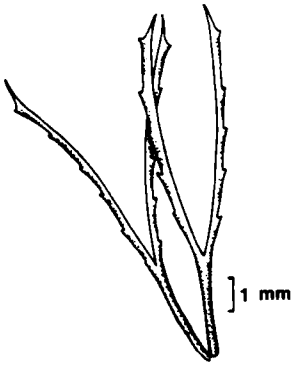
**Description:** Submersed, floating perennial, often rooted. Leaves of two types: those floating narrowly elliptic, constricted at the middle, to 2 cm long, attached at its center by the petiole; those submersed opposite, finely divided. Flowers from the axils of the upper leaves, cream-colored, composed of 6 petal-like parts to 8 mm long. Fruit leathery.

**Habitat:** (FA;O). This species is most frequently found in slow streams and in ponds.

**Distribution and Uses:** (12356). Found mostly in the eastern United States. This is one of seven species in the genus. All are found in warm regions of the Western Hemisphere.








***Ceratophyllum demersum* L.**

**Common Name:** Coontail; hornwort.

**Description:** Submersed perennial with much-branched stems and no roots. Leaves in groups of 5-8 along the stem, to 3 cm long, each leaf palmately divided into narrow segments and with conspicuous teeth along the margins. Flowers inconspicuous in the axils of the leaves. Fruits hard, to 6 mm long, with 3 spines.

**Habitat:** (FA;O). Occurs in standing water, often forming dense colonies.

**Distribution and Uses:** (1234567890AHCWPEM). This is one of the most abundant freshwater aquatics, found in both the Old World and the New World. The fruits, which are produced in great abundance during the summer, as well as the foliage, are a food source for waterfowl.

**Notes:** This is the only submersed aquatic with whorled leaves that are palmately divided. A second species, *C. muricatum* Cham. (syn.: *C. echinatum* Gray), has more spines per fruit and is apparently less common. *Ceratophyllum* may be confused with Chara (musk grass); however, *Chara* is an alga with a garlic odor.

***Myriophyllum aquaticum* (Vell.) Verdc.**

**(Syn.: *M. brasiliense*)**

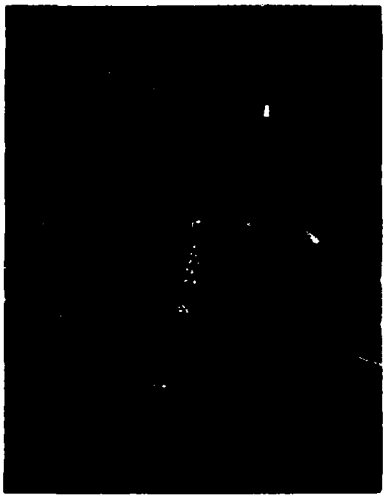
**Common Name:** Parrotfeather.

**Description:** Submersed/emersed perennial with unbranched stems to 1.5 m tall. Leaves 4-6 in a whorl, each leaf gray-green and divided into 18 pairs of threadlike segments resembling a feather. Flowers unisexual, inconspicuous, in the axils of the leaves.

**Habitat:** (FA;O). Lakes, ponds, and canals. This species spreads by fragmentation.

**Distribution and Uses:** (12356790). Native to South America. Parrotfeather provides cover for aquatic organisms.

**Note:** This species differs from other milfoils by having its foliage emersed to 20 cm out of the water. The emersed foliage is bright green.



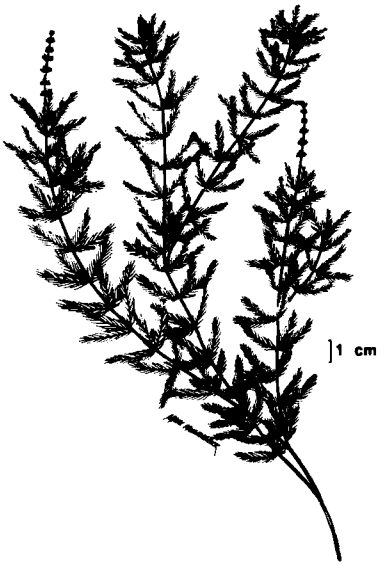
***Myriophyllum spicatum* L.**

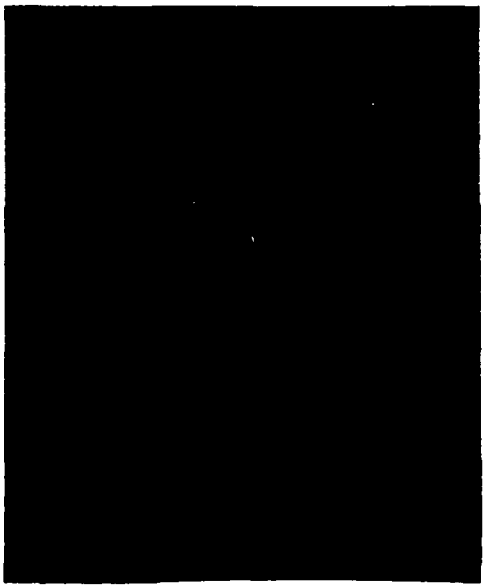
***Common Name:*** *Eurasian watermilfoil.*

**Description:** Submersed perennial; rooting in mud. Stems branched, usually purple, to 3 m long. Leaves in whorls of 3 or 4, seldom more, pinnately divided into 6-16 pairs of threadlike leaflets. Flowers unisexual, borne in whorls, the staminate ones above the pistillate ones. Petals 4 per flower, only 2.0-2.5 mm long. Fruit nearly spherical, 2-3 mm in diameter.

**Habitat:** (FA;O). Lakes, ponds, streams, and estuaries, both in fresh and brackish water, sometimes in water to 5 m deep.

**Distribution and Uses:** (1234567890ANWPEM). Throughout the United States, as well as Europe and Asia. The fruits and stems are eaten by waterfowl.



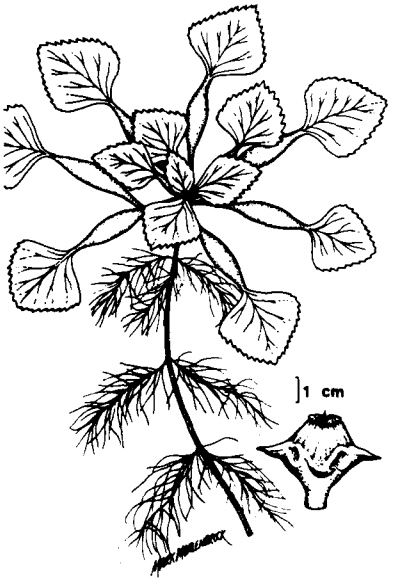
***Trapa natans* L.**

**Common Name:** Waterchestnut.

**Description:** Perennial; stems submersed or floating, surface smooth, to 2 m long. Submersed leaves threadlike, far apart on the stems; *floating leaves forming a rosette*, nearly triangular or diamond-shaped, toothed in the upper half, 2-4 cm long, on inflated petioles to 15 cm long. Flowers in the axils of the leaves, with 4 white petals to 8 mm long, blooming from June to September. Fruit nutlike, to 5 cm broad, with a few stout thorns.

**Habitat:** (FA;O). Lakes, ponds, slow streams, and rivers, rooted in mud.

**Distribution and Uses:** (1) Under favorable conditions, particularly in the Potomac River and other rivers of the Northeast, this species may become very abundant and form impenetrable mats. It is a native of Europe and Asia.



***Utricularia gibba* L.**

**Common Name:** Cone-spur bladderwort.

**Description:** Perennial; stems submersed, very slender, to 10 cm long forming a mat of intertwined stems. Leaves alternate, once or sometimes twice branched, threadlike, 3-5 mm long, bearing a few bladders. Flowers 1-3 in a cluster, borne above the water, with a short, blunt spur, yellow, 5-6 mm long. Fruit a capsule, nearly spherical, about 4 mm in diameter.

**Habitat:** (FA;O). Ponds, lakes, swamps, slow-moving steams.

**Distribution and Uses:** (1235690CEM). This species occurs throughout most of North America, in Central America, and in the West Indies. It flowers from June to September.

**Note:** The bladders act as traps for capturing insect larvae and fish fry.

***Utricularia inflata* Walt.**

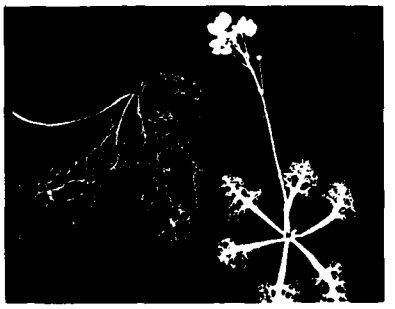
**Common Name:** Big-floating bladderwort.

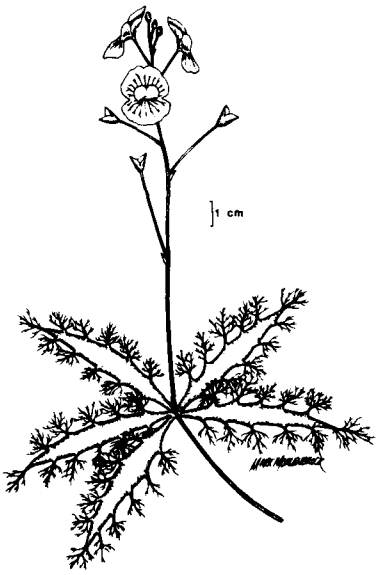
**Description:** Perennial; stems submersed, to 1 m long. Floating leaves, alternate or in whorls of 4-7, attached to thickened, inflated floats (petioles), the floats to nearly 8 cm long; submersed leaves with bladders, alternate, forked 4-6 times. Flowers 6-10 in a cluster, borne above the water, with a short spur, yellow, about 1.5 cm long. Fruit a capsule, nearly round, 3-6 mm in diameter.

**Habitat:** (FA;O). Ponds, lakes, swamps, slow-moving steams. During periods of low water, this species may survive in the mud for a considerable amount of time.

**Distribution and Uses:** (1,2,6) This species is confined to the Coastal Plain, from Delaware around to Texas. It flowers from May to July.

**Note:** This species may sometimes bear a tiny tuber at the end of some of the branches.





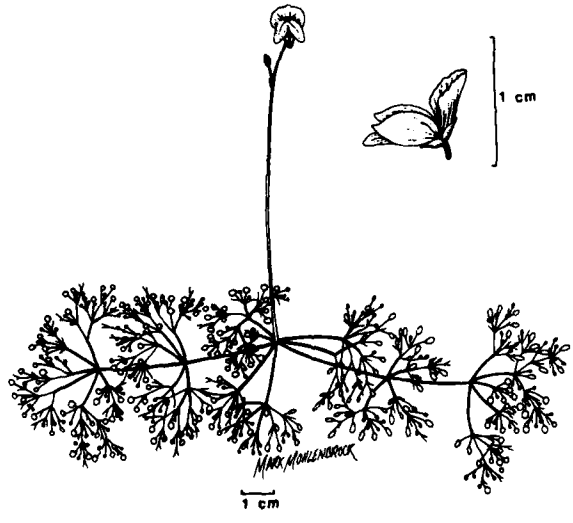
***Utricularia purpurea* Walt.**

**Common Name:** Purple bladderwort.

**Description:** Perennial; stems submersed, to 1 m long. Leaves 5-7 in a whorl, divided into threadlike segments, some of which terminate with a small bladder. Flowers 1-5 in a cluster, borne above the water, with a spur 2-5 mm long, purple, one of the petals with a yellow spot at the base, about 1 cm long. Fruit a capsule, spherical, 3-4 mm in diameter.

**Habitat:** (FA;O). Quiet water, ponds, swamps, slow-moving streams.

**Distribution and Uses:** (1236EM). In addition to occurring in the eastern United States, this species also grows in the West Indies and Central America. It flowers from July to September.



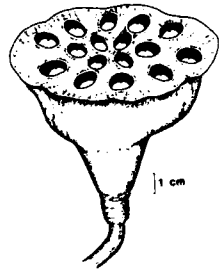

***Nelumbo lutea* (Willd.) Pers.**

**Common Names:** American lotus; lotus lily; water chinquapin.

**Description:** Emersed perennial from thick, circular rhizomes. Leaves spherical, to 70 cm across, attached at the center by the petiole, usually elevated above the water surface. Flower solitary, pale yellow, to 25 cm across, composed of numerous petals, blooming during the summer, to 10 cm across, becoming woody and containing hard seeds about 1 cm in diameter.

**Habitat:** (FA;O). Lakes, quiet streams and rivers, often forming extensive colonies.

***Distribution and Uses:*** (12356E). Mostly in the eastern United States. The seeds are eaten by waterfowl. The starchy rhizomes are edible.




***Nuphar luteum* (L.) Sibth. & Small**
(Syn.: *N. advena* (Ait.) Ait. f.)

**Common Names:** Spatterdock; yellow water-lily.

**Description:** Emersed perennial with thick rhizomes. Leaves ovate, heart-shaped at the base, shiny, smooth, to 40 cm long, some of the leaves floating but most of them standing above the water. Flower solitary on a long stalk, formed slightly above the water surface from May to August, 3-5 cm in diameter, with 5 or 6 thick, yellow, petal-like parts surrounding several stamens and a swollen pistil. Fruit leathery.

**Habitat:** (FA;O). Swamps, lakes, ponds, slow-moving streams, and other standing water, often forming extensive colonies.

**Distribution and Uses:** (1234567890ANWPEM). Throughout North America. The fruits are eaten by aquatic animals and waterfowl. The underwater rhizomes contain starch and are edible.

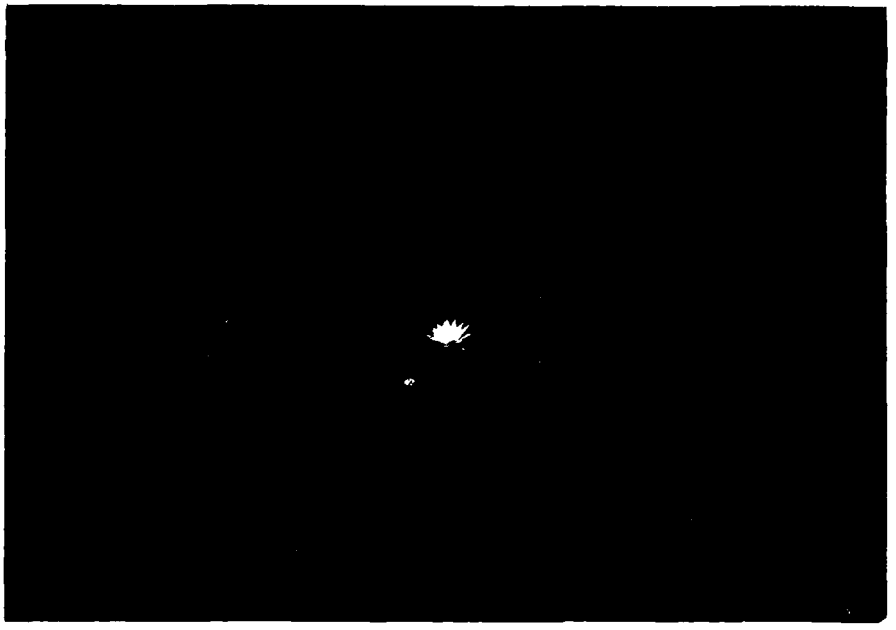
***Nymphaea odorata* Ait.**

**Common Name:** Fragrant waterlily.

**Description:** Emergent perennial with thick rhizomes. Leaves often spherical, cleft at base, smooth, to 25 cm across, often purple on the lower surface, most of the leaves floating. Flower solitary on long stalks, borne at the surface of the water or elevated slightly above it, fragrant, opening in the morning during the summer, each flower to 12 cm across, usually white or occasionally pink, with numerous petals.

**Habitat:** (FA;O). Ponds, lakes, quiet streams, often forming dense colonies.

**Distribution and Uses:** (12356789CPEM). Found throughout much of North America. The seeds are eaten by waterfowl, although they are not a major food source.



***Ludwigia uruguayensis* (Camb.) Hara**
(Syn.: *Jussiaea uruguayensis* Camb.)

**Common Name:** Water primrose.

**Description:** Perennial; stems floating, or upright if terrestrial, covered with long hairs. Leaves alternate, simple, lanceolate to oblanceolate, hairy, the margins without teeth, to 5 cm long, to 2.5 cm broad; petioles hairy, to 1.5 cm long. Flowers in the axils of the upper leaves, with 4 yellow petals to 2 cm long. Fruit is a capsule to 5 cm long.

**Habitat:** (FA;FM;FS;O). Lakes, ponds, slow streams, and swamps.

**Distribution and Uses:** (123690). Although this species is native to South America, it has spread into the eastern half of the United States.

**Note:** Plants of this species can form large floating mats.

***Polygonum arifolium* L.**

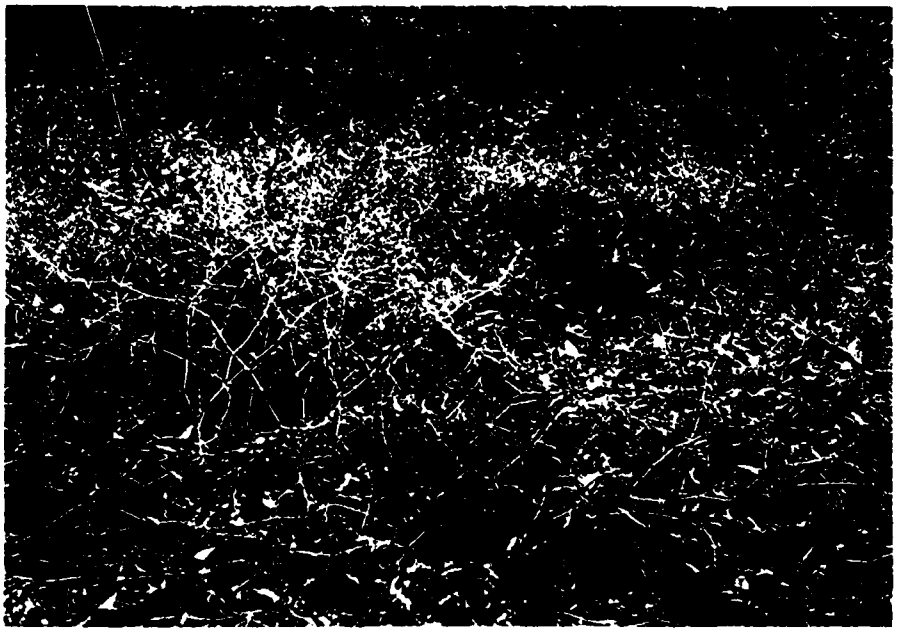
**Common Name:** Tearthumb.

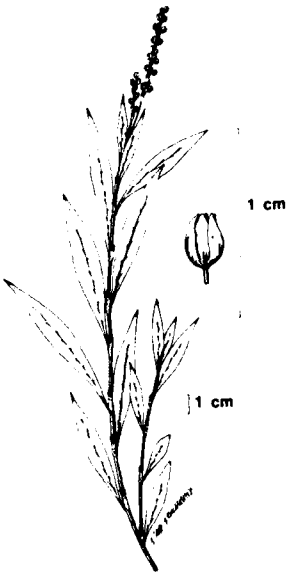
**Description:** Annual; stems with downward pointing barbs, to 2 m long, usually lying on other plants. Leaves arrowhead-shaped, with two spreading lobes at the base, hairy, the margins without teeth, usually 5-10 cm long, 3-7.5 cm broad. Flowers pink, few in a cluster, about 2.5 mm long. Fruit an achene, flat, brown or black, 3.5-4.5 mm long.

**Habitat:** (FM;FS;O). This species is found in marshes and swamps; it can form tall, dense stands.

**Distribution and Uses:** (123EM). Tearthumb is confined to the eastern half of the United States.

**Note:** This species flowers during August and September.






***Polygonum hydropiperoides* Michx.**

**Common Name:** Smartweed.

**Description:** Rhizomatous perennial. Stems upright, to 1 m tall, but with the lower part of the stem rooting at the nodes, smooth or slightly hairy. Leaves alternate, simple, narrowly lanceolate, margins without teeth, smooth or sparsely hairy, to 6 cm long, to 1.2 cm broad. Flowers white or pink, 5-parted, borne in slender racemes. Achenes black, smooth, shiny, 1.8-2.5 mm long.

**Habitat:** (FM;FS;O). Wet soil; sometimes in standing water. It can form dense stands covering ditches and canals.

**Distribution:** (1234567890AWEM). Found throughout most of North America. The achenes are eaten by waterfowl.

**Notes:** Flower color varies from white to pink. This species flowers from July to September.

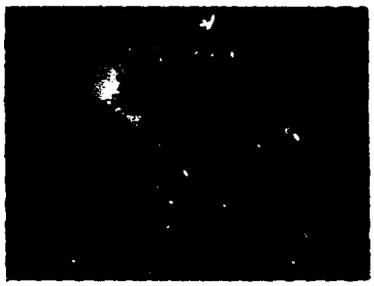
***Ranunculus aquatilis* L.**
(Syn.: *R. trichopyllus* Chaix)

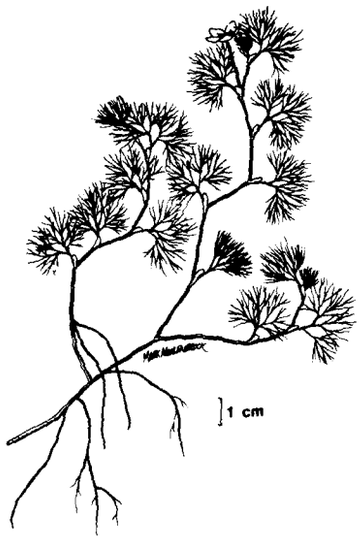
**Common Name:** Water buttercup.

**Description:** Submersed perennial with stems to 1 m long. Leaves finely dissected into numerous segments that collapse upon removal from water. Flowers to 1.5 cm broad, with usually 5 white petals to 7 mm long. Fruit a beaked achene.

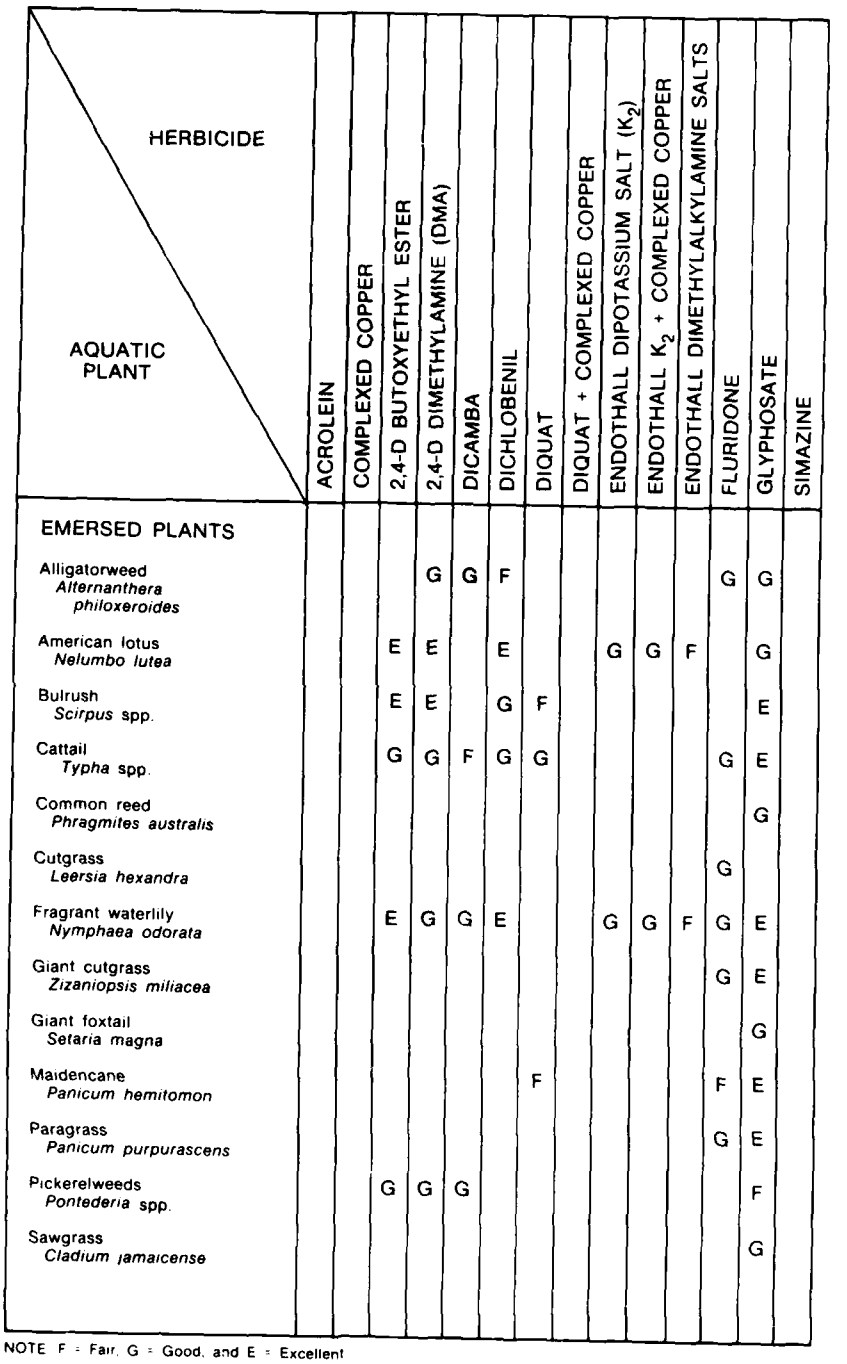
**Habitat:** (FA;O). This species may grow in either fresh or brackish water.

**Distribution and Uses:** (123457890ANWPEM). Throughout North America, except for the Southeast; also in Europe and Asia. The fruits are eaten by waterfowl.





## PLANT SUSCEPTIBILITY



| AQUATIC PLANT \ HERBICIDE | ACROLEIN | COMPLEXED COPPER | 2,4-D BUTOXYETHYL ESTER | 2,4-D DIMETHYLAMINE (DMA) | DICAMBA | DICHLOBENIL | DIQUAT | DIQUAT + COMPLEXED COPPER | ENDOTHALL DIPOTASSIUM SALT ($K_2$) | ENDOTHALL $K_2$ + COMPLEXED COPPER | ENDOTHALL DIMETHYLALKYLAMINE SALTS | FLURIDONE | GLYPHOSATE | SIMAZINE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EMERSED PLANTS** | | | | | | | | | | | | | | |
| Alligatorweed *Alternanthera philoxeroides* | | | | G | G | F | | | | | | G | G | |
| American lotus *Nelumbo lutea* | | | E | E | | E | | | G | G | F | | G | |
| Bulrush *Scirpus* spp. | | | E | E | | G | F | | | | | | E | |
| Cattail *Typha* spp. | | | G | G | F | G | G | | | | | G | E | |
| Common reed *Phragmites australis* | | | | | | | | | | | | | G | |
| Cutgrass *Leersia hexandra* | | | | | | | | | | | | G | | |
| Fragrant waterlily *Nymphaea odorata* | | | E | G | G | E | | | G | G | F | G | E | |
| Giant cutgrass *Zizaniopsis miliacea* | | | | | | | | | | | | G | E | |
| Giant foxtail *Setaria magna* | | | | | | | | | | | | | G | |
| Maidencane *Panicum hemitomon* | | | | | | | F | | | | | F | E | |
| Paragrass *Panicum purpurascens* | | | | | | | | | | | | G | E | |
| Pickerelweeds *Pontederia* spp. | | | G | G | G | | | | | | | | F | |
| Sawgrass *Cladium jamaicense* | | | | | | | | | | | | | G | |

NOTE F = Fair, G = Good, and E = Excellent

## PLANT SUSCEPTIBILITY

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EMERSED PLANTS (Cont.) | | | | | | | | | | | | | | |
| Smartweeds *Polygonum spp.* | | | G | G | E | G | F | | G | G | | F | F | |
| Southern watergrass *Hydrochloa caroliniensis* | | | | | | | | | | | | G | | |
| Spatterdock *Nuphar luteum* | | | E | G | G | G | | | G | G | F | G | E | |
| Torpedograss *Panicum repens* | | | | | | | | | | | | G | E | |
| Waterchestnut *Trapa natans* | | | G | | | | | | | | | | | |
| Water paspalum *Paspalum fluitans* | | | | | | | F | | | | | G | | |
| Water pennywort *Hydrocotyle umbellata* | | | G | G | G | | E | E | | | | | | |
| Water primrose *Ludwigia uruguayensis* | | | E | E | | F | F | | F | F | F | F | | |
| Watershield *Brasenia schreberi* | | | E | E | | E | F | F | G | G | F | G | | |
| Waterwillow *Justicia americana* | | | | E | | | F | | | | | G | | |
| FLOATING PLANTS | | | | | | | | | | | | | | |
| Duckweed *Lemna minor* | | | G | G | E | | E | E | F | | | E | | E |
| Giant duckweed *Spirodela polyrhiza* | | | G | G | E | | E | E | | | | G | | E |
| Mosquito fern *Azolla caroliniana* | | | F | F | | | G | G | | | | G | | |

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| AQUATIC PLANT \ HERBICIDE | ACROLEIN | COMPLEXED COPPER | 2,4-D BUTOXYETHYL ESTER | 2,4-D DIMETHYLAMINE (DMA) | DICAMBA | DICHLOBENIL | DIQUAT | DIQUAT + COMPLEXED COPPER | ENDOTHALL DIPOTASSIUM SALT ($K_2$) | ENDOTHALL $K_2$ + COMPLEXED COPPER | ENDOTHALL DIMETHYLALKYLAMINE SALTS | FLURIDONE | GLYPHOSATE | SIMAZINE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FLOATING PLANTS (Cont.)** | | | | | | | | | | | | | | |
| Salvinia *Salvinia rotundifolia* | | | | | | | E | E | F | | | G | | |
| Slender duckweed *Wolffiella floridana* | | | | | | | G | | | | | G | | G |
| Waterhyacinth *Eichhornia crassipes* | | | | E | E | | E | E | F | F | F | | F | |
| Waterlettuce *Pistia stratiotes* | | | F | | | | E | E | G | | | | G | |
| Watermeal *Wolffia columbiana* | | | | | | | G | | | | | F | | G |
| **SUBMERSED PLANTS** | | | | | | | | | | | | | | |
| Bladderworts *Utricularia* spp. | | | G | | | G | G | | | | | G | | |
| Coontail *Ceratophyllum demersum* | G | | F | F | | E | E | E | E | E | E | G | | G |
| Egeria *Egeria densa* | G | | | | | G | G | E | E | E | E | G | | |
| Elodea *Elodea canadensis* | G | | | | | E | E | E | | F | G | G | | |
| Eurasian watermilfoil *Myriophyllum spicatum* | | | E | E | | G | E | E | E | E | E | G | | G |
| Fanwort *Cabomba caroliniana* | | | F | F | | | G | E | E | E | E | G | | G |
| Horned pondweed *Zannichellia palustris* | G | | F | F | | E | | | E | E | E | F | | F |
| Hydrilla *Hydrilla verticillata* | F | G | | | | F | G | E | G | G | G | G | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SUBMERSED PLANT (Cont.) | | | | | | | | | | | | | | |
| Naiads *Najas* spp. | G | | F | | | E | E | E | E | E | E | G | | E |
| Parrotfeather *Myriophyllum aquaticum* | F | | E | E | E | F | E | E | E | E | E | | F | |
| Pondweeds *Potamogeton* spp. | G | | | | | E | G | G | E | E | E | G | | E |
| Water buttercup *Ranunculus aquatilis* | F | | | | | E | E | E | | F | | | | |
| Widgeongrass *Ruppia maritima* | F | | | | | E | G | E | F | F | F | | | |
| Wildcelery *Vallisneria americana* | G | | | | | F | F | F | | | F | | | G |

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## REGISTERED HERBICIDES

## ACROLEIN

A. ***Chemical Name and Formulation***:
Chemical name: 2-propenal
Formulation: MAGNACIDE H HERBICIDE

B. ***Mode of Action***: Acrolein is a contact herbicide. It causes plant cell disruption through destruction of vital enzyme systems in the plant cells.

C. ***Application***: Dosage rates should be from 0.6 to 11 ℓ/cu m/sec (0.16 to 3 gal/cu ft/sec). Application time range is 0.5 to 48 hr. Repeated applications may be necessary at 2- to 3-week intervals. The acrolein must be injected beneath the water surface, using polyethylene tubing, to maintain it in a liquid state. Only nitrogen gas completely free of oxygen should be used. NOTE: Application equipment may be purchased from the herbicide manufacturer.*

D. ***Timing of Application***: Apply when the target plants are no more than 15 cm (6 in.) long and the water temperature is greater than 20°C (68°F). Application may be made at lower temperatures; however, reaction time will be longer.

E. ***Application Rates***: Acrolein should be applied at full strength, i.e., 92% acrolein, 0.78 kg active ingredient/ℓ (6.5 lb ai/gal).

F. ***Maximum Water Concentration***: No tolerance has been established for acrolein in potable water. Treated irrigation water reaching crops must not exceed 15 mg/ℓ (ppm).

G. ***Use Restrictions***: Acrolein must not be used where treated water flows or transfers to suspected sources of drinking water.

H. ***Waiting Period***: Treated water should not be released to any fish-bearing waters, or where it will drain into them until 6 days after application.

I. ***Toxicological Data***: Fish are killed when exposed to acrolein concentrations greater than 1 mg/ℓ (ppm).

J. ***Precautions***:
- Acrolein must not be used where a fish kill cannot be tolerated.
- Acrolein volatilization causes eye irritation and tearing; therefore, care must be exercised to ensure its release below the water surface.
- Swimming should not be allowed in treated water until acrolein residues are nondetectable.

K. ***Field Instructions***:
- A preventive maintenance program is recommended, consisting of a series of acrolein applications throughout the growing season so that aquatic plants are never allowed to exceed 15 cm (6 in.) in length.

L. ***Adjuvant Use***: Use of adjuvants is not specified.

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* A listing of herbicide manufacturers is provided on page 101.

**M.** ***Application Techniques*:**

- Subsurface, uniform injection of acrolein into quiescent water throughout the infested area or an irrigation/drainage canal is required, following instructions provided by Magna Corporation.
- Subsequent retreatment should occur based upon rate of plant regrowth.

**N.** ***Antidote Information*:**

**CALL A PHYSICIAN IMMEDIATELY!**

- ***Internal*:** If the material has been swallowed, give two glasses of water and induce vomiting immediately by introducing finger into the throat. If inhaled, get victim into fresh air immediately and give artificial respiration if breathing has stopped.
- ***External*:** If spilled on the skin, remove all contaminated clothing and wash skin with soap and running water. If material gets into eyes, wash immediately with water for 15 minutes.

## COPPER COMPLEXES

**A.** ***Chemical Name and Formulations*:**
Chemical name: Copper chelates
Formulations:

- CUTRINE-PLUS (9% Cu, ethanolamine complex, liquid)
  Also, CUTRINE-PLUS granular (3.7% Cu)
- KOMEEN (8% Cu, ethylenediamine complex, liquid)
- KOPLEX Same as above
- K-TEA (8% Cu, triethanolamine complex, liquid)

**B.** ***Mode of Action*:** Copper complexes act as cell toxicants and are not subject to photolysis or volatilization.

**C.** ***Application*:** Liquid formulations are applied using a hand or power sprayer and a drip system. From a boat, liquids are injected below the water surface or through weighted hoses dragging along the bottom. Ivert emulsions of KOMEEN should be injected below the water surface. Granular formulations are applied using a hand-operated or boat-mounted Gandy-type broadcast spreader.

**D.** ***Timing of Application*:** To obtain most effective results, apply before plants reach the water surface, preferably on a sunny day when the water temperature is above 15°C (60°F).

**E.** ***Application Rates*:** CUTRINE-PLUS should be applied at 0.4 to 1.0 mg/ℓ Cu (1.2-3.0 gal/acre-ft) (ppm) to control *Hydrilla* (3-hr contact time is required in lotic environments). KOMEEN, KOPLEX, and K-TEA are applied at 57 to 150 ℓ/ha (6 to 16 gal/acre) to control *Hydrilla*. (Recommended dose is based on site-specific water volume, not surface area.)

**F.** ***Maximum Water Concentration*:** Copper concentration should not exceed 1 mg/ℓ (potable water) by weight copper.

**G.** ***Use Restrictions*:**

- Do not apply when water temperature is below 15°C (60°F). (Copper ions form insoluble copper hydroxides, phosphates, and carbonates in water with pH > 7.) (This does not apply when using chelated copper.)
- Currently, there are no restrictions on the use of treated water immediately following treatment.
- Some states require a permit when CUTRINE-PLUS is used in public water. This would apply to any copper product or herbicide.

**H.** ***Waiting Period*:** Effect on target species can be observed in 7 to 10 days after treatment (CUTRINE-PLUS); 3 to 6 days, with full effects manifested in 4 to 6 weeks (KOMEEN/KOPLEX).

I. ***Toxicological Data*:**

| Species | Chemical | Hardness* (mg/ℓ as $CaCO_3$) | Exposure Period hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|---|
| Cutthroat trout | Copper chloride | 18-205 | 96 | 15.7-367 |
| Rainbow trout | Copper chloride | 42-194 | 96 | 57-574 |
| White perch | Copper nitrate | 53 | 96 | 6,200 |
| Striped bass | Copper nitrate | 53-55 | 96 | 4,000-4,300 |
| Bluegill sunfish | Copper chloride | 43 | 96 | 1,250 |
| Largemouth bass | Copper nitrate | 100 | 96 | 6,970 |

* In soft or acid water, trout and certain other species of fish may be killed at recommended treatment rates.

J. ***Precautions*:**

- Water hardness must be considered prior to treatments.
- Should not be used where pH of water or spray environment is below 6, because of copper ion formation and subsequent toxicity to fish.
- Contact with skin and eyes may be irritating.

K. ***Field Instructions*:**

- Effect of treatment will be observed within 4 to 6 weeks. In heavily infested areas, a second application after 12 weeks may be necessary.

L. ***Adjuvant Use*:**

- For spraying *Hydrilla*, Nalquatic polymer is a recommended adjuvant with KOMEEN. (Both KOMEEN and KOPLEX can be inverted with an adjuvant or used in combination with diquat.)
- When KOMEEN is applied as an invert emulsion, xylene and an emulsifying agent are normally used.

M. ***Application Techniques*:**

- Apply chemical uniformly over the surface of infested area.
- Treat from shoreline outward toward the center of the water body, preventing entrapment of fish within the treated area.
- In heavily infested, smaller water bodies, treat only one-third to one-half of the area at a time; allow 1 to 2 weeks between successive treatments.

- Apply with hand or power sprayer, drip system, or any other method to provide even distribution over the treatment area. (See label recommendations.)

**N. *Antidote Information:***

- Thoroughly wash contaminated skin and eyes.
- If swallowed, call a doctor.
- Since KOMEEN, K-TEA, and CUTRINE-PLUS have no appreciable vapor pressure, there is no hazard from inhalation.

## 2,4-D

A. ***Chemical Name and Formulations***:

Chemical name: (2,4-dichlorophenoxy) acetic acid

*Formulations:*

- AQUA-KLEEN (19% acid equivalent (ae), butoxethyl ester of 2,4-D, granular)
- WEEDAR 64 (38.9% ae, dimethylamine or n-alkylamine salt of 2,4-D, liquid)
- WEED-RHAP A-6D (57.4% ae, dimethylamine or n-alkylamine salt of 2,4-D, liquid)
- VISKO-RHAP A-3D (33.92% ae, dimethylamine or n-alkylamine salt of 2,4-D, liquid)
- WEEDTRINE II (18.8% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)
- WEED-RHAP LV-4D (46.3% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)
- VEGATROL LV-6D (62.5% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)
- ESTERON 99 (43.4% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)
- SEE 2,4-D (40.9% ae, isooctyl or 2-ethylhexyl ester of 2,4-D, liquid)

B. ***Mode of Action:*** Somewhat selective, systemic growth regulator with hormonelike activity; readily translocated throughout plant, especially from foliage to roots; inhibits cell division of new tissue and stimulates cell division of some mature plant tissues, resulting in growth inhibition, necrosis of apical growth, and eventually, total cell disruption and plant death; low concentrations may stimulate growth.

C. ***Application:***

- Liquid formulations:

  Surface or aerial applications; subsurface application for submersed vegetation.

  Surface applications with dilute or concentrated product, using conventional spray equipment from boat or shore.

  Aerial spraying with dilute product; do not exceed 40 psi at the nozzles.

  Subsurface applications using weighted trailing hoses from boat.

- Granular formulations:

  Surface of aerial applications using conventional mechanical spreaders or comparable equipment for large areas or a portable spreader for spot treatments.

- Ester formulations are volatile and care should be exercised when considering their use, particularly in aerial applications.

D. ***Timing of Application***: For best results, apply in spring or early summer when young vegetation is actively growing.

E. ***Application Rates***: Follow herbicide label directions for specific rates.
- Liquid formulation:
  Waterhyacinth and emersed vegetation control: 2 to 4 kg ae per hectare (2 to 4 lb/acre) (2 to 3.8 ℓ of 38.9% ae formulation per hectare) (2 to 4 pints/acre).
- Canal bank vegetation control: 1 to 2 kg ae per hectare (1 to 2 lb/acre).
- Watermilfoil control (TVA system): 9.5 to 38 kg ae per hectare (10 to 40 lb ae/acre); 23 to 93 ℓ of WEEDAR 64 per hectare) (2.5 to 10 gal/acre); use concentrate for more dilute formulations (e.g., 38.9% ae) or diluted mixture for more concentrated formulations; use higher rate for areas with heavier infestations.
- Granular formulation:
  Submersed vegetation control: 20 to 40 kg ae per hectare (20 to 40 lb ae/acre); use higher rate for areas with heavier infestations.

F. ***Maximum Water Concentration***: Should not exceed 0.1 mg/ℓ (ppm); delay use of of treated water for irrigation for 3 weeks posttreatment unless an approved assay shows water does not contain more than 0.1 mg/ℓ (ppm) 2,4-D acid. Low persistence in water, with half-life less than 2 weeks.

G. ***Use Restrictions***:
- Liquid formulations registered for use solely for floating (e.g., waterhyacinth) and emergent vegetation control; AQUA-KLEEN and WEEDAR 64 allowed for Eurasian watermilfoil control in TVA lake systems only.
- Special Local Needs (Section 24c) and Emergency Exemption (Section 18) labels may exist in some states.
- Do not use treated water for irrigation, agricultural sprays, livestock watering, or domestic water supplies for 3 weeks after application or unless approved assay above water does not contain more than 0.1 mg/ℓ (ppm) 2,4-D acid. Amine formulations may be tested at concentrations as low as 0.001 mg/ℓ (ppm).
- Do not spray liquid during high wind conditions, to minimize spray drift to nontarget vegetation.
- Can be used in slow-moving water bodies and turbid water.
- Liquid formulations registered for treating canal and ditchbank emergent vegetation in 17 western states (see label).
- Contact state or local fish and game agency for specific restrictions on fishing, swimming, or domestic use.

H. ***Waiting Period***: Approximately 2 weeks for control of most vegetation; tissue damage evident within 2 to 4 days with liquid and a week with granular formulations. Regrowth evident within 4 to 5 weeks if roots are not killed.

I. ***Toxicological Data:***

| Species | 2,4-D Formulation* (% ae) | Conditions | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|---|
| Lake trout | 2,4-D acid (100%) | Static | 96 | 35-56 |
| Bluegill sunfish | 2,4-D BEE (65.2%) | Static | 96 | 1.1-1.3 |
| Fathead minnow | 2,4-D BEE (65.2%) | Static | 96 | 2.5-4.2 |
| Rainbow trout | 2,4-D DMA (49%) | Static | 96 | >100 |
| Bluegill sunfish | 2,4-D DMA (49%) | Static | 96 | 123-230 |
| Fathead minnow | 2,4-D DMA (49%) | Static | 96 | 245-458 |
| Amphipod (*Gammarus fasciatus*) | 2,4-D BEE (62.5%) | Static | 96 | 4.5-8.3 |
| Cladoceran (*Daphnia magna*) | 2,4-D BEE (62.5%) | Static | 96 | 4.5-9.1 |
| Amphipod (*G. fasciatus*) | 2,4-D IOE (67%) | Static | 96 | 1.9-3.0 |
| Amphipod (*G. fasciatus*) | 2,4-D DMA (49%) | Static | 96 | >100 |

* BEE = butoxyethyl ester; DMA = dimethylamine salt; IOE = isooctyl ester.

- Ester formulations of 2,4-D are 50 to 200 times more toxic to fish than amine formulations, but toxic effects are rarely observed under field conditions.
- Ester and amine formulations of 2,4-D appear more toxic at low pH (e.g., 6.5) versus higher pH.

J. ***Precautions:***

- To prevent low dissolved oxygen, do not retreat water until killed vegetation decomposes, about 4 to 5 weeks after initial application. Do not treat entire water body at one time; treat in strips separated by buffer zones.
- Avoid spray drift outside treatment area; do not conduct aerial spraying if wind speed is above 8 km per hour (5 mph); use drift control agents.
- Do not treat areas of water lacking aquatic vegetation.
- Follow directions carefully if using oil-soluble amine formulations, requiring a two-fluid spray system.
- Avoid application of liquid formulations during high wind or flow conditions.

K. ***Field Instructions:***

- Use spray drift-control agents (e.g., thickeners, invert emulsions) with liquid formulations; use coarse sprays.
- Apply liquid and granular formulations in strips separated by buffer zones.
- Delay follow-up treatment for 4 to 5 weeks after initial application to allow for vegetation decomposition.
- Use higher treatment rate for heavily infested areas or if water is unusually high in pH and alkalinity.
- Use proper equipment and recommended mixtures when applying oil-soluble amine formulations.
- Do not enter treated area without protective clothing until spray has dried.

L. ***Adjuvant Use:***

- Polymeric thickeners or invert emulsions are recommended with liquid formulations, especially when sprayed on floating or emersed vegetation.
- Oil-soluble amine formulations (e.g., VISKO-RHAP A-3D) require premixing with kerosene or related oil-soluble solvent; use required mixing equipment.

M. ***Application Techniques:***

- When applying by boat, divide formulation so as to provide material for application in a crisscross pattern; apply back and forth, with sharp turns, followed by an equivalent application at right angles to the first set.
- Recommend placing markers at corners of treatment area to use as directional guides and to avoid excessive overlap of treatments.
- Recommend use of 15- to 30-m (50- to 100-ft) treatment lanes separated by equivalent-sized buffer zones; treatment immediately adjacent to shore is not recommended or needed.

N. ***Antidote Information:***

- ***Internal***: If swallowed, induce vomiting by touching back of throat or give strong salt water to drink; repeat until vomit is clear. Call a physician immediately and the following emergency number, collect (24 hr a day): (304) 744-3487 (Rhone-Poulenc).
- ***External***: Wash skin with soap and water. Flush eyes with water for at least 15 minutes and get medical attention.

## DICAMBA

A. ***Chemical Name and Formulation:***
Chemical name: 3,6-dichloro-o-anisic acid
Formulation: BANVEL 720 (10.6% dicamba + 20.4% 2,4-D, dicamba dimethylamine, liquid)

B. ***Mode of Action:*** Selective herbicide absorbed and translocated from both leaves and roots with major accumulation in apical meristems and other areas with high metabolic activity; growth hormonelike properties; causes epinasty, defoliation, swelling of stems, and destruction of conductive tissues, death of growing points, loss of apical dominance, and ultimately, necrosis.

C. ***Application.*** Water-soluble liquid is applied as a surface spray from shoreline, boat, or helicopter; mixed with water, plus emulsifiers, surfactants, or drift control agents. Completely wet emergent foliage to runoff with dilute spray mix.

D. ***Timing of Application.*** Do not apply prior to emergence of vegetation above or to surface of water. Plants are most sensitive during their active growing stage.

E. ***Application Rates:***
- Ground or boat application: use 2 to 6 kg active ingredient (ai) (2 to 6 qt liquid/surface acre) in 50 to 100 gal spray mix, as directed on label. Aerial application: use 1.5 to 5 kg ai per hectare (1.5 to 5 qt liquid/surface acre) in 8 to 20 gal spray mix, as directed on label.
- Cattail treatment requires 4 to 6 kg ai per hectare (4 to 6 lb/surface acre) plus 6 kg dalapon 85% per hectare (6 lb dalapon 85% per surface acre).

F. ***Maximum Water Concentration:*** Not specified; not for direct application to water bodies. Half life is 2 to 6 weeks in most water bodies.

G. ***Use Restrictions:***
- Treated water should not be used for irrigation purposes within 14 days of application.
- Do not graze dairy animals on treated area for 7 days after treatment.
- Direct application to water is not permitted.
- Do not contaminate water used for domestic purposes.
- Registration for aquatic use is presently limited to 10 states (Alabama, Florida, Georgia, Indiana, Louisiana, Mississippi, South Carolina, Tennessee, Texas, and Virginia).

H. ***Waiting Period:*** None specified.

I. ***Toxicological Data:****

| Species | Condition | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Rainbow trout | Static, 12°C (54°F) | 96 | 28 |
| Bluegill sunfish | Static, 12°C (54°F) | 96 | >50 |
| Amphipod (*Gammarus fasciatus*) | Static, 15°C (59°F) | 96 | >100 |
| Cladoceran (*Daphnia magna*) | Static, 21°C (70°F) | 48 | >100** |

* Data are for 88% technical dicamba; the dimethylamine salt formulations may show slightly greater toxicity.

** EC-50 was evaluated.

- Herbicide formulation shows low order of toxicity to fish, other aquatic organisms, and wildlife.

J. ***Precautions:***

- Harmful if swallowed; shows extreme irritation to eyes and mild irritation to skin; not readily absorbed through skin.
- Avoid excess spraying of soil as herbicide is readily leached from soil.
- Do not use aerial application if sensitive crops or nontarget plants are growing in immediate vicinity.
- Do not apply during periods of gusty wind or if wind exceeds 24 km per hour (15 mph).
- Do not spray submersed vegetation in water, only emergent growth.

K. ***Field Instructions:***

- Avoid heavy application to soil or excessive runoff from vegetation; wet vegetation thoroughly, however.
- Avoid spray drift; use drift-reducing additives.
- Do not use aerial equipment in areas adjacent to sensitive crops or desirable vegetation.
- Follow label instructions for proper cleaning of equipment.

L. ***Adjuvant Use:*** Recommend use of oil-water emulsions, including invert systems, or other spray drift-reducing agent.

M. ***Application Techniques:***

- Use coarse-spray nozzles and spray drift retardants (foams or invert system) to avoid drift to nontarget vegetation.
- Avoid spraying across areas of water lacking emergent vegetation.
- Avoid application during high or gusty wind conditions.

- Prior to large-scale mixing, perform a compatibility test, using all spray mix components in small quantities; if herbicide does not form a gel, precipitate, or stratification, the spray mix is compatible.

**N. *Antidote Information*:**

- ***Internal***: If swallowed, drink 1 to 2 glasses of water and induce vomiting by sticking finger down back of throat (or other means). Do not induce vomiting if victim is unconscious. Call a physician.
- ***External***: Flush eyes with plenty of water for at least 15 minutes and get medical attention. Wash exposed skin thoroughly with soap and water; wash contaminated clothing before reuse.

## DICHLOBENIL

**A.** ***Chemical Name and Formulations***:
Chemical name: 2,6-dichlorobenzonitrile
Formulations:

- CASORON 10G (10% ai, dichlobenil, granular)
- NOROSAC 10G (10% ai, dichlobenil, granular)
- CASORON G-SR (20% ai, dichlobenil, slow-release, granular)
- CASORON G Forte (20% ai, granular)

**B.** ***Mode of Action***: Nonselective herbicide that is absorbed mainly by roots but also by submersed leaves and stems upon being released from granules in water column; causes disruption of plant cell division, resulting in plant deterioration. Major route of action seems to be through the soil to the roots.

**C.** ***Application***:

- Granular formulations can be applied from boat or shoreline to water surface.
- Uniform distribution is essential since each granule is active only in its immediate surroundings.
- Applied to nonflowing waters and to dry bottoms and shorelines of ponds, reservoirs, and lakes.
- Dichlobenil can be applied to flowing water at 1.5 times the recommended dosage rate for slow-moving water.

**D.** ***Timing of Application***: Application immediately before initiation of new growth provides the best results, such as in early spring.

**E.** ***Application Rates***:
Water surface:

| Water Depth m (ft) | Granules 10G kg/ha (lb/acre) |
|---|---|
| <0.6 (<2) | 111 (100) |
| 0.6-1.5 (2-5) | 139 (125) |
| >1.5 (>5) | 166 (150) |

Exposed bottom: Evenly spread 70 to 100 kg/ha (lb/acre); use the lower rate if the soil is wet at time of application or if the water is <1 ft deep. Ponds or reservoirs with drawdown should be refilled promptly after treatment.

**F.** ***Maximum Water Concentration***: No values are given, but 3 mg/ℓ (ppm) is recommended. Herbicide tends to be readily absorbed to sediment and rapidly and completely broken down in water within 2 weeks. Effective dose of active ingredient is 2 to 3 mg/ℓ (ppm).

G. ***Use Restrictions***:
- Treated water should not be used for livestock or human consumption or crop irrigation.
- A 90-day waiting period is required prior to use of fish from treated water for food or feed.
- Not recommended for use in commercial fish or shellfish waters.

H. ***Waiting Period***: Existing revegetation is controlled very slowly. Therefore, dichlobenil should be applied in early spring before weed growth begins. This produces a season-long weed control period. Algae are not controlled.

I. ***Toxicological Data***: Recommended dosages provide dichlobenil concentrations well below the danger levels to spawning fish, phytoplankton, and other food chain organisms.

| Species | Conditions | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Rainbow trout | Static, 13°C (55°F) | 96 | 6.3 |
| Bluegill sunfish | Static, 18°C (64°F) | 96 | 8.3 |
| Crustacea (*Daphnia pulex*) | Static, 1st instar, 15°C (59°F) | 96 | 3.7 |
| Crustacea (*Grammarus lacustris*) | Static, mature 21°C (70°F) | 96 | 11.0 |

Variations in water hardness have little effect on fish toxicity. Toxicity of the principal metabolite, 2,6-dichlorobenzamide, is much less than dichlobenil.

J. ***Precautions***:
- Dichlobenil is not selective in action and may kill all types of vegetation in contact with the active ingredient.
- Store in tightly closed containers in a dry place.
- Do not treat water needed for crop irrigation within a 4-week period.
- Avoid breathing dust from product.

K. ***Field Instructions***:
- Even application of granules is required for effective control since each granule is active mainly in its immediate surroundings.
- The herbicide is directly absorbed by plants, especially by roots through the sediment.
- Avoid application near desirable vegetation as this herbicide is nonselective.
- If applied to drained surfaces, refill with water as soon as possible to avoid volatilization of active ingredient.
- Dispose of empty bags in a sanitary landfill or by incineration if allowed by state or local authorities.

L. ***Adjuvant Use***: Use of adjuvants is not specified.

M. ***Application Techniques***:

- Good results are obtained by motorized knapsack applicators, used from a boat or shore.
- Long stretches of canals and ditches can be treated with tractor-mounted equipment.
- Application should be made during periods of calm, when wave action or water flow rate is minimal.
- Avoid excessive propeller turbulence if using a motorboat.

N. ***Antidote Information***:

- ***Internal:*** Induce vomiting by drinking water and touching back of throat with finger (or other means). Call a physician immediately.
- ***External:*** Flush eyes with water for 15 minutes. Wash skin thoroughly with soap and water. If inhaled, remove individual to fresh air.

## DIQUAT

A. ***Chemical Name and Formulations***:
Chemical name: 6,7-dihydrodipyrido(1,2-∝:2',1'-c) pyrazinediium dibromide
Formulations:
- Ortho DIQUAT - H/A (35.3% ai, diquat dibromide)
- WEEDTRINE-D (8.53% ai, diquat dibromide)

B. ***Mode of Action***: Contact type, nonselective, absorbed by foliage but not by buried roots due to rapid inactivation by clay minerals; causes rapid inactivation of cells and cellular functions through release of strong oxidents; only local translocation.

C. ***Application***:
- Water-soluble liquid; surface or aerial spray for floating vegetation; surface or bottom application with trailing hoses for submersed vegetation.
- Herbicide concentrate or up to 20:1 dilution with water is recommended for subsurface injection; aerial sprays should be diluted 15- to 400-fold with water, depending on plant species or growth stage (see label).
- Efficacy is greatly reduced in muddy water or with mud-coated vegetation.
- Can be used in quiescent or flowing water (Ortho DIQUAT only).
- Mixture with complexed copper formulations often provides improved efficacy.

D. ***Timing of Application***: Throughout the entire growing season; recommend control of early growth. One application per growing season anticipated.

E. ***Application Rates***:
- Submersed vegetation: 9.4 to 18.7 ℓ/ha (8 to 16 pt/surface acre) (add 3.4 to 5.6 kg/ha (3 to 5 lb/acre) copper ion complex for hydrilla, coontail, and bladderwort).
- Floating vegetation: 4.7 to 7.0 ℓ/ha (4 to 6 pt/surface acre) (except duckweed: 9.4 to 18.7 ℓ/ha (8 to 16 pt/surface acre).
- Marginal emersed vegetation: 9.4 ℓ (8 pt/surface acre).
- Filamentous algae: 3.5 to 9.4 ℓ/ha (3 to 8 pt/surface acre) (average water depth).

F. ***Maximum Water Concentration***: Do not exceed 2 mg/ℓ.

G. ***Use Restrictions***:
- Do not use water for animal or human consumption, swimming, or spraying within 14 days of treatment unless approved analysis shows that water does not contain more than 0.01 mg/ℓ diquat ion.

- Do not use herbicide in muddy water or on vegetation coated with mud.
- Treat only one-third to one-half of densely vegetated areas at a time and wait 10 to 14 days between treatments.

H. ***Waiting Period***: Plants absorb diquat rapidly; plant decline is usually within less than 7 days posttreatment.

I. ***Toxicological Data***:

| Species | Condition | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Channel catfish | Static | 96 | 10 |
| Largemouth bass | Static | 96 | 7.8-10 |
| Bluegill sunfish | Static | 96 | 10-140 |
| Rainbow trout | Static | 96 | 5-11.2 |
| Fathead minnow | Static | 96 | 14.0 |
| Cladoceran (*Daphnia pulex*) | Static | 192 | 1.0 |
| Midge larvae | Static | 96 | >100 |

J. ***Precautions***:

- Avoid spray drift to food, forage, or desirable vegetation; do not store or transport near feed or food.
- Do not get diquat on skin, eyes, or clothing; may be fatal if ingested, inhaled, or absorbed through skin; symptoms of injury may be delayed; strong skin irritant.
- Use facemask, gloves, and waterproof clothing and footwear while spraying or when reentering treated areas.

K. ***Field Instructions***:

- Recommend use of nonionic surfactant (e.g., Ortho X-77 spreader) or thickener (e.g., Nalquatic) when spraying floating or emersed vegetation.
- Do not treat muddy water or vegetation coated with mud; use clean water for making herbicide dilutions.
- Avoid creating muddy water during application.
- Do not apply under conditions of high wind or wave action.
- Treat heavy plant infestations in sections; subsequent treatment should be after a 10-day waiting period to avoid low dissolved oxygen levels.
- Subsurface injections should be done in strips, 12.2 m (40 ft) apart with early growth and not more than 6.1 (20 ft) apart in thick mature growth.
- Treat with complexed copper.

**L. *Adjuvant Use*:**

- For aerial application, use nonionic surfactant (e.g., Ortho X-77 Spreader) at rate of 0.47 ℓ (1 pt) surfactant per 568 to 757 ℓ (150 to 200 gal) spray mixture.
- Use of a polymeric thickener (e.g., Nalquatic) is recommended for submersed growth at rate of 3.79 ℓ (8 pt) per 379 to 568 ℓ (100 to 150 gal) mixture.
- Complexed copper ion in combination with diquat is recommended for improved efficacy for some macrophytes (hydrilla, coontail, bladderwort) and algae control.

**M. *Application Techniques*:**

Use water carrier, thickener, or invert emulsion carrier for best results.

- Submersed vegetation:

  Boat with weighted trailing hoses, apply dilute concentrate 7.6 to 15 cm (3 to 6 in.) below water surface or (for firm sediments) 31 to 61 cm (1 to 2 ft) off bottom.

  Boat with sprayer, use concentrate poured directly from original containers; apply in strips with widths of 6.1 m (20 ft) (new growth) to 12.2 m (40 ft) (topped-out mature growth).

- Floating or emergent vegetation:

  Use conventional spray equipment from boat, shore, or helicopter, using techniques for minimizing spray drift.

  Use nonionic surfactant *with dilute tank mix*.

**N. *Antidote Information*:**

- ***Internal***: If conscious, give large amount of water to drink and force vomiting by placing finger at back of throat (or by other method). Call a physician immediately and the following emergency numbers: (800) 845-7633 (South Carolina: (800) 922-0193) for National Agricultural Chemical Association Medical Hotline or (415) 233-3737 for Chevron Chemical Company emergency information.
- ***External***: Flush eyes and skin immediately with water for at least 15 minutes. For eyes, get medical attention. Remove and wash contaminated clothing before reuse and daily during treatment period.

## ENDOTHALL

**A.** ***Chemical Name and Formulations***:

Chemical name: 7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid

Formulations:

- AQUATHOL K (40.3% ai, dipotassium salt of endothall, liquid)
- AQUATHOL Granular (10.1% ai, dipotassium salt of endothall, granular)
- HYDROTHOL 191 (53.0% ai, mono(N,N-dimethylalkylamine) salt of endothall, liquid)
- HYDROTHOL 191 (11.2% ai, mono(N,N-dimethylalkylamine) salt of endothall, granular)

**B.** ***Mode of Action***: Contact type, membrane-active herbicide that inhibits protein synthesis upon plant metabolism; limited translocation throughout plant tissues.

**C.** ***Application***:

Liquid suspension: total water column treatment, bottom water treatment, invert and polymer additions.

Granules: surface application of water body.

General information:

- Formulations can be used in quiescent and flowing water (irrigation and drainage canals); canal treatment not allowed in California.
- Dimethylalkylamine salt of endothall (granular form) for use in rice paddies in California only.

**D.** ***Timing of Application***: Apply soon after emergence of new vegetative growth. Water temperature should be at least 65°C (18° C prior to application.

**E.** ***Application Rates***:

- *Dipotassium salt of endothall*:

  Quiescent water - (Average depth): 72 to 119 ℓ/ha (62-102 pt/acre) liquid; 374 to 631 ℓ/ha (320-540 lb/acre) granules.

  Irrigation and drainage canals - Not for use in canals in California.

  Herbicide contact time with target plants should be at least 2 hr.

  Recommended water concentrations for target plants are given in the tabulation that follows.

| Plant | Entire Pond or Large Area Treatment, mg/ℓ | Sectional or Lake Margin Treatment, mg/ℓ |
|---|---|---|
| Hydrilla | 2-3 | 3-4 |
| Watermilfoil | 2-3 | 3-4 |
| Waterstargrass | 2-3 | 3-4 |
| Pondweeds | 1-3 | 2-4 |
| Coontail | 1-2 | 2-3 |
| Horned pondweed | 1-2 | 2-3 |
| Naiads | 0.5-1.5 | 2-3 |

- Mono(N,N-dimethylalkylamine) salt of endothall:

  Quiescent water - Formulation recommended only for sectional or marginal treatment of water bodies stocked with fish, due to relatively high fish toxicity.

  Irrigation and drainage canals - Herbicide contact time with target plants should be at least 2 hr.

- Recommended water concentrations for target plants:

  Quiescent water - 0.5 to 2.5 mg/ℓ. Use dosages over 1 mg/ℓ only *on very narrow margins or in areas* where some fish kill is not objectionable. Do not treat more than 10 percent of water body at one time with more than 1 mg/ℓ.

  Canals - Heavy infestations: 3-5 mg/ℓ.
  Moderate to light infestations: 1-2 mg/ℓ.

**F. *Maximum Water Concentration*:**

Dipotassium salt of endothall; Do not exceed 5 mg/ℓ, although low toxicity to fish is indicated.

Mono(N,N-dimethylalkylamine) salt of endothall: Do not exceed 2.5 mg/ℓ; only small sectional or marginal areas of water bodies containing fish should exceed water concentrations greater than 1 mg/ℓ.

G. ***Use Restrictions***:

| Usage | Dipotassium Endothall | Dimethylalkylamine Endothall |
|---|---|---|
| Swimming | 24 hr | 24 hr |
| Drinking water (humans and livestock) | 7-14 days | ≤0.3 mg/ℓ, 7 days<br>0.3-3.0 mg/ℓ, 14 days<br>3.0-5.0 mg/ℓ, 25 days |
| Fish consumption (from treated water) | 3 days | 3 days |
| Irrigation of nonfood crops | 7 days | 7 days |
| Release of water from rice fields (California only) | Not applicable | 10 days (granular only) |
| In muddy water water | Yes | Yes |
| In slow-flowing water | Yes | Yes |

H. ***Waiting Period***: Target plants show initial signs of tissue damage (necrosis) within 1 to 3 days; control of vegetation is usually obtained in 7 to 14 days.

I. ***Toxicological Data***:

**Dipotassium endothall**:

| Species | Conditions | Exposure Period | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Largemouth bass | Static | 48 hr | 200-320 |
| Largemouth bass | Flowthrough | 96 hr | >135 |
| Largemouth bass | Repeat exposure | 7 days | 95-115* |
| Chinook salmon | Static | 96 hr | 82 |
| Chinook salmon | Repeat exposure | 14 days | 62.5 |
| Bluegill sunfish | Static | 96 hr | 125 |
| Bluegill sunfish | Repeat exposure | 21 days | 100* |
| Rainbow trout | Repeat exposure | 21 days | 10* |
| Crustacea (*Grammarus lacustris*) | Static | 96 hr | >320 |
| Midge larvae | Static | 72 hr | 120 |

* Concentration producing minimal or no mortality.

**Dimethylalkylamine endothall:**

| Species | Conditions | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Largemouth bass | Static | 96 | 0.1-0.3* |
| Bluegill sunfish | Static | 48 | 0.8 |
| Bluegill sunfish | Static | 96 | 0.06-0.2* |
| Redear sunfish | Static | 96 | 0.1-0.2* |
| Golden shiner | Flowthrough | 120 | 0.32-1.6 |

* Diamine salt.

- Dimethylalkylamine salt of endothall is more toxic than the dipotassium salt to fish and other nontarget organisms.
- Increasing water temperature causes a slight increase in toxicity of this formulation.
- Rapid microbial decomposition of endothall precludes its bioaccumulation.
- No hazardous metabolites have been noted to form.

**J. *Precautions*:**

- Do not use fish from treated water for food or feed within 3 days of treatment.
- Do not use water for domestic purposes until 7 to 14 days after treatment (see Use Restrictions).
- Fish will be killed by dosages of dimethylalkylamine endothall in excess of 0.3 mg/ℓ.
- Do not use dimethylalkylamine formulation in marine or estuarine environments due to high toxicity to estuarine organisms.
- Avoid breathing spray mist. Potentially harmful skin absorption is possible if bathing and change of clothing are not initiated daily during use.
- Causes severe eye and skin irritation; wear goggies and rubber gloves while handling concentrate. Harmful or fatal if swallowed.

**K. *Field Instructions*:**

- Necessary approval and/or permits should be obtained.
- Small infested areas best treated with granular products.
- Adjuvant polymers aid in application of liquid products and may allow lower applicaton rates.
- Dimethylalkylamine formulation should be applied by professional applicator.
- Most algae can be effectively treated with dimethylalkylamine endothall or dipotassium endothall in combination with complexed copper.

- Treat water containing heavy vegetation in sections to prevent low dissolved oxygen levels caused by vegetation decay.
- Treat surface vegetation with undiluted liquid formulations.
- Apply liquid herbicide when wind and water flow rate are minimal to prevent rapid dispersal from treatment area.

**L. *Adjuvant Use*:** Polymeric adjuvants (e.g., Nalquatic) with dipotassium salt formulations and Nalcotrol II for mono(N,N-dimethylalkylamine) salt formulation or invert emulsions for liquid formulations.

**M. *Application Techniques*:**

- Liquid formulations:
  Aerial, surface application by boat or from shore, and bottom placement of liquids by boat with trailing hoses.
  Recommend use with adjuvants especially for surface water application.
  Low-dilution applications are recommended for partly emersed plants.
  Bottom placement is recommended for bottom growth.
  Metering devices are recommended for applications to flowing water (ditches and canals).
- Granular formulations:
  Aerial and surface application from boat or shore, by blowers or mechanical spreaders.

**N. *Antidote Information*:**

- ***Internal***: Promptly drink large quantities of milk, egg whites, or gelatin solution, or if these are not available, large quantities of water. Avoid alcohol. Measures against circulatory shock, respiratory depression, and convulsion may be needed. Call a physician immediately and the following emergency numbers: (800) 845-7633 (South Carolina: (800) 922-0193) for National Agricultural Chemical Association Medical Hotline or (206) 627-9101, ext. 250, for Pennwalt Corporation emergency information.
- ***External***: Flush eyes or skin for at least 15 minutes with plenty of water. For eyes, call a physician. Remove and wash contaminated clothing before reuse. Bathe and wash clothing daily during treatment period.

## FLURIDONE

**A.** ***Chemical Name and Formulations***:

Chemical name: 1-methyl-3-phenyl-5-[-3(trifluoromethyl)phenyl] -4(1H)-pyridinone

Formulations:

- SONAR 4AS (43.2% ai, fluridone, liquid emulsion)
- SONAR 5P (5% ai, fluridone, pellet)
- SONAR SRP (5% ai, fluridone, slow-release pellet)

**B.** ***Mode of Action***: Systemic, from submersed foliage to roots or emersed foliage; also absorbed from sediment. Inhibits carotenoid synthesis and thus affects photosynthesis.

**C.** ***Application***:

Liquid suspension: to water surface, subsurface, or along bottom of water body.

Pellets: surface application of water body. Use only in quiescent lakes and ponds, with little water movement, to avoid rapid dilution; for control of both submersed emersed vegetation.

Ponds: treat entire water body.

Lakes and reservoirs: Establish plots no less than 10 surface acres. Do not treat areas with a large linear aspect, e.g., boat lakes and shorelines.

**D.** ***Timing of Application***: During spring or summer when weeds are visible and actively growing.

**E.** ***Application Rates***:

| Treatment Area | Water Depth, m | Liquid, ℓ/ha | Pellets, kg/ha |
|---|---|---|---|
| Ponds | 0.9 | 1.17-2/34* | 11.2-22.4 |
| | 0.9-1.5 | 2.34-3.5 | 22.4-33.6 |
| Lakes/reservoirs | 1.5 | 0.88-1.75 | 0.56-0.84 |
| | 0.9-1.5 | 1.75-3.5 | 0.84-1.12 |
| | 1.5-3.1 | 3.5-4.7 | 1.12-1.68 |
| | 3.1 | 1.75-3.5 | 16.8-33.6 |
| | 1.8-3.7 | 3.5-7.0 | 33.6-67.2 |
| | 3.7 | 4.7-9.4 | 44.8-89.6 |

* *The higher rate should be used with dense growth or greater water depth through* treatment area.

**F.** ***Maximum Water Concentration***: Not specified; initial water concentration of approximately 0.1 mg/ℓ is recommended.

G. ***Use Restrictions***: Do not apply within 0.25 mile (0.4 km) of any potable water intake. See "Irrigation Precautions" on label.

H. ***Waiting Period***: Visible herbicidal effects should be noticed on target plants within 7 to 10 days after application, by the appearance of pink or chlorotic growing points. Sixty to ninety days may be required to determine the effectiveness of the herbicide on the target vegetation.

I. ***Toxicological Data***:

| Species | Conditions | Exposure Time | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Rainbow trout | Static | 96 hr | 7.6-11.7 |
| Bluegill sunfish | Static | 96 hr | 9.0-12.5 |
| Channel catfish | Static | 96 hr | 22 |
| Cladoceran (*Daphnia magna*) | Static | 48 hr | 4.4-6.3 |
| Catfish eggs/larvae | Repeat exposure | Chronic | >0.5 |
| Fathead minnow | Repeat exposure | Chronic | >0.5 |
| *Daphnia* reproduction | Repeat exposure | Chronic | >0.2 |

- NOTE: Fluridone was not found to cause genetic mutations or cancer in tested lab animals.

J. ***Precautions***: Avoid contact with eyes, skin, or clothing. Harmful if swallowed, inhaled, or absorbed through skin.

K. ***Field Instructions***:
- Avoid application during high-flow conditions (e.g., after heavy rain or high wind conditions).
- Suspended particulates or muddy water should not greatly affect herbicidal action.
- Avoid application near desirable shoreline trees or shrubs having roots extending into water.
- Herbicide is not effective against algae and, thus, an algicide may be required.
- Emptied container should be rinsed three times with rinse water from the spray tank. Dispose of container by burying, offer for recycling or reconditioning, or puncture and dispose in a sanitary landfill.

L. ***Adjuvant Use***: None specified.

M. ***Application Techniques***:
- May be applied with any available (liquid or pellet) application equipment; uniform application is desirable but not necessary.
- Application of spray or pellets may be from shore or boat.

- No information concerning aerial application or spray drift problems.

**N.** ***Antidote Information:***

- ***Internal***: No specific information; get medical help immediately. Call physician and emergency telephone number (317) 276-3342 (ELANCO).
- ***External***: For eyes and skin, flush with plenty of water; get medical attention if irritation persists.

## GLYPHOSATE

A. ***Chemical Name and Formulation***:
Chemical name: N-(phosphonomethyl)glycine
Formulation: RODEO (53.5% ai, isopropylamine salt of glyphosate, liquid)

B. ***Mode of Action***: Not definite. However, investigators have postulated that biosynthesis of phenylalanine is interrupted through repression of chorismatic acid.

C. ***Application***: To aerial foliage, water soluble; do not apply to submersed or mostly submersed vegetation.

D. ***Timing of Application***: When plants are actively growing.

E. ***Application Rates***:
- Alligatorweed: 7.9 ℓ/ha (6 pt/acre) as broadcast spray; 1.25% solution with hand-held equipment.
- Cattail, maidencane, paragrass, spatterdock: 7.0 ℓ/ha (6 pt/acre) as broadcast spray; 0.75% solution with hand-held equipment.
- Giant cutgrass, waterhyacinth: 7.0 ℓ/ha (6 pt/acre) as broadcast spray; 1% solution with hand-held equipment.
- Torpedograss: 7.0 to 8.8 ℓ/ha (6 to 7.5 pt/acre) as broadcast spray; 0.75 to 1.5% solution with hand-held equipment.
- Other listed perennials: 5.3 to 8.8 ℓ/ha (4.5 to 7.5 pt/acre) as broadcast spray; 0.75 to 1.5% solution with hand-held equipment.

F. ***Maximum Water Concentration***: None is specified; approved for use at all aquatic sites. Recommended concentration is 0.2 mg/ℓ.

G. ***Use Restrictions***:
- No restriction on use of treated water for irrigation, recreation, or domestic purposes.
- Do not apply within 0.8 km (0.5 mile) upstream of potable water intakes.
- Do not exceed 8.8 ℓ/ha (7.5 pt/acre) for each treatment.
- Do not retreat within 24 hr.

H. ***Waiting Period***: Visible effects on most annual plants occur within 2 to 4 days, but perennial plants may not show effects for 7 days or more. Visible effects are gradual wilting and yellowing of plant, advancing to total browning and deterioration. In fact, effects may not appear for up to 4 weeks depending on physiological state of the plants.

I. ***Toxicological Data*:**

| Species | Condtions* | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ** |
|---|---|---|---|
| Rainbow trout | Static | 96 | 7.0-11.0 |
| Bluegill sunfish | Static | 96 | 4.2-14.0 |
| Channel catfish | Static | 96 | 11.0-16.0 |
| Cladoceran (*Daphnia magna*) | Static | 48 | 5.3 |

* Toxicity increased with increasing temperature and alkalinity.

** 41% liquid (ROUNDUP).

J. ***Precautions*:**

- Do not mix or store this product in galvanized or unlined steel (except stainless steel) due to production of combustible gas (hydrogen).
- Avoid contact with eyes, skin, or clothing.
- Avoid spray drift.

K. ***Field Instructions*:**

- Long-term exposure causes corrosion of most exposed metal equipment, unless thoroughly washed after use.
- Rainfall or washing of plants within 6 hr of application can reduce herbicide effectiveness.
- Use of an approved nonionic surfactant is required with this herbicide.
- This product does not provide residual weed control.
- Do not use muddy water for diluting spray solutions due to herbicide inactivation following particulate sorption.

L. ***Adjuvant Use*:** Surfactant use is required. Use 0.25 to 0.5% surfactant by total spray volume (950 to 1,892 ml/379 ℓ (1 to 2 qt/100 gal) spray solution). Trademark surfactants: Agri-Dex, Cide-Kick, Induce, Liqua-wet, Ortho X-77, Passage, R-11, Spreader Sticker, Super Spread 200, and Widespread.

M. ***Application Techniques*:** Aerial (except in California), high volume, or hand-held equipment. Drift control additives may be used. Spray to wet foliage without runoff. Use the least amount of water, as possible, to provide adequate foliar wetting.

N. ***Antidote Information*:**

- ***Internal***: Call physician and emergency number: (314) 694-4000 (Monsanto).
- ***External***: Eyes should be flushed with plenty of water for at least 15 minutes; skin should be flushed with water; and clothing should be washed before reuse.

## Simazine

A. ***Chemical Name and Formulation***:
Chemical name: 2-chloro-4,6-bis(ethylamino)-s-triazine
Formulation: AQUAZINE (80% ai, simazine, wettable powder)

B. ***Mode of Action***:
- Relatively selective, systemic herbicide with species-specific translocation properties.
- Primary action is by blockage of photosynthesis (electron transport pathways), but rapid action implies other phytotoxic effects, including increased photooxidation through pigment destruction reactions.
- Uptake results in rapid foliar chlorosis followed by necrosis and destruction of all cellular tissues and organelles.
- Low concentrations cause leaf greening and stimulate growth.

C. ***Application***: Using water as the carrier, apply wettable powder as paste or slurry to surface of water at several points from shoreline, or spray dilute slurry suspension over surface of pond. Conventional spray equipment can be used.

D. ***Timing of Application***: Early spring applications are best, i.e., after emergence and before heavy plant growth occurs. Application before water temperature exceeds 24°C (75°F) allows for slower vegetation decay and decreased oxygen stress on aquatic organisms.

E. ***Application Rates***:
- Submersed and floating vegetation:
  1.16 - 2.33 kg/ha (3.4 - 6.8 lb/acre-ft)
  [(0.92 to 1.85 kg ai/ha (2.7 - 5.4 lb ai/acre-ft)], giving concentration of 1 to 2 ppm. For watermeal control, split application and apply half 3 to 4 weeks after first treatment. Use higher rate for heavy infestations. For fanwort, use: 2.91 kg/ha (8.5 lb/acre-ft) [(2.33 kg ai/ha) (6.8 lb ai/acre-ft)].
- Sensitive algae are usually controlled at doses half those for aquatic macrophytes.

F. ***Maximum Water Concentration***: None specified; should not exceed maximum recommended application of 2.5 mg ai/ℓ.

G. ***Use Restrictions***:
- Water from treated ponds may not be used for irrigation, spraying of nontarget vegetation, watering of domestic animals, or for human consumption until 12 months following treatment.
- Fish from treated ponds may be used for human consumption.
- Treated ponds may be used immediately for swimming.

H. ***Waiting Period*:**

- Control of submersed plants, except coontail, occurs in 4 to 6 weeks; coontail, in 10 weeks.
- Control of duckweeds occurs in 1 to 5 weeks; watermeal, in 5 to 9 weeks.
- Most algae are controlled within 1 week; bluegreen algae are most rapidly controlled.

I. ***Toxicological Data*:** (Technical material, 98.1%, except as stated.)

| Species | Conditions | Exposure Period, hr | Acute Toxicity $LC_{50}$, mg/ℓ |
|---|---|---|---|
| Rainbow trout | Static, 12°C | 96 | >100 |
| Fathead minnow | Static, 25°C | 96 | 6.4 - >100 |
| Bluegill sunfish | Static | 96 | 16.0 |
| Bluegill sunfish | Static, 24°C | 96 | 90 - 110* |
| Amphipod (*Gammarus fasciatus*) | Static, 15°C | 96 | >100 |
| Cladoceran (*Daphnia magna*) | Static, 21°C | 48 | 0.56 - 2.2** |

* Wettable powder, 80%.

** $EC_{50}$ values.

J. ***Precautions*:**

- Do not treat ponds with bordering trees having roots that extend into water; do not spray or spill herbicide on desirable vegetation.
- Avoid contact with skin, eyes, or clothing; wear gloves and long-sleeved shirts and pants. Wash thoroughly after handling and before eating. Use dust aspirator and goggles if inhalation and eye contact with powder is likely.
- Clean equipment with water and discard into treated water; do not use water for irrigation or domestic use within a 12-month period.
- Avoid storage of herbicide at high temperature or in moist areas; normal shelf life is more than 5 years.

K. ***Field Instructions*:**

- Approved for farm and recreational ponds, including those containing edible fish.
- Do not use herbicide for spot treatments, due to its slow rate of action.
- Although formulation can be applied as a powder, it it best to use as a slurry or spray by mixing with water over the water surface.

L. ***Adjuvant Use***: None.

M. ***Application Techniques***: Mix convenient quantity of wettable powder (e.g., 2.26 to 4.5 kg (5 to 10 lb) with water to form thin paste or slurry. Pastes can be applied to several evenly spaced locations along pond shoreline, or uniformly applied as a dilute slurry over pond surface with spray equipment.

N. ***Antidote Information***:

- ***Internal***: If large dose is ingested, induce vomiting by placing finger at back of throat; due to its low oral toxicity, special action is not required if insignificant quantities are ingested. Call a physician immediately if a large dose is ingested.
- ***External***: Flush eyes with plenty of water for at least 15 minutes; get medical attention if irritation persists.
  - Wash exposed skin surfaces vigorously with soap and water.
  - If inhaled, move to fresh air; give artificial respiration if needed.
  - Wash contaminated clothing before reuse.

# HERBICIDE MANUFACTURERS

NOTE: This listing does not include all suppliers of the herbicide products. Consult one of the listed manufacturers for the nearest supplier in your area.

**Acrolein**

Magna Corporation
Pacheco and Gosford Roads
Bakersfield, CA 93311

**Complexed Copper**

Applied Biochemists, Inc.
5300 West County Line Rd.
96 North
Mequon, WI 53092
(414) 242-5870
1-800-558-5106

Kocide Chemical Corp.
12701 Alameda Rd.
Houston, TX 77045
(713) 433-6404

**2,4-D**

Rhone-Poulenc, Inc.
Agrochemical Division
PO Box 125
Monmouth Junction, NJ 08852

Velsicol Chemical Corp.
World Headquarters
341 E. Ohio
Chicago, IL 60611
(312) 670-4500

InterAg, Inc.
5100 Poplar Ave., 24th Floor
Memphis, TN 38137
(901)767-6851

**Dicamba**

Velsicol Chemical Corp.
(see 2,4-D)

**Dichlobenil**

Uniroyal Chemical Company, Inc.
World Headquarters
Middlebury, CT 06740

**Diquat**

Applied Biochemists, Inc.
(see Complexed Copper)

Chevron Chemical Co.
940 Hensley St.
Richmond, CA 94804

Also:
Chevron Chemical Co.
Agricultural Pesticides Div.
575 Market St.
San Francisco, CA 94105
(415) 894-7800

**Endothall**

Pennwalt Corporation
Ag Chemical Division
3 Parkway
Philadelphia, PA 19102
(215) 587-7219

**Fluridone**

Elanco Products Co.
Division of Eli Lilly Company
740 South Alabama St.
Indianapolis, IN 46285
(317) 261-3000

**Glyphosate**

Monsanto Chemical Co.
800 No. Lindbergh Blvd.
St. Louis, MO 63167
(314) 694-1000

**Simazine**

Ciba-Geigy Corporation
PO Box 18300
Greensboro, NC 27419
(919) 292-7100

# AQUATIC PLANT INDEX

(includes family, genera, species, and common names)

# INDEX

**Notes:**